PUBLIC SPENDING DETERMINANTS ON ENVIRONMENTAL MANAGEMENT IN BRAZIL

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ABSTRACT

Objective: The objective of this article was to analyze the determinants of public spending on environmental management in the states of Brazil from 2011 to 2020.

Theoretical Framework: Spending on the environment becomes a parameter to measure the commitment of governments to environmental sustainability. The green budget has the potential to finance the transition to a greener economy and to support the implementation of public policies that aim to mitigate and adapt to climate change.

Method: We used the panel data methodology with three different types of regression, namely pooled, fixed-effects, and random-effects models. The study population consists of the capitals of Brazil from 2011 to 2020, resulting in a total of 270 observations.

Results and Discussion: The results obtained revealed that GDP per capita and the proportion of expenditures in relation to GDP emerge as significant and relevant variables. In addition, the HDI also showed positive significance, suggesting that an increase in the capital's HDI is associated, according to the model, with an increase in environmental spending.

Research Implications: Analyzing the determinants of public spending on the environment can contribute to decision-making and the development of better public policies.

Originality/Value: This study contributes to the literature by analyzing the determinants of public spending on environmental management in the states of Brazil from 2011 to 2020.

Keywords: Environmental Spending, Human Development Index, Total Spending, Gross Domestic Product.

DETERMINANTES DOS GASTOS PÚBLICOS EM GESTÃO AMBIENTAL NO BRASIL

RESUMO


Referencial Teórico: Os gastos com o meio ambiente se tornam um parâmetro para medir o comprometimento dos governantes com a sustentabilidade ambiental. O orçamento verde tem o potencial de financiar a transição

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para uma economia mais verde e de apoiar a implementação de políticas públicas que visam mitigar e adaptar-se às mudanças climáticas.

Método: Utilizou-se a metodologia de dados em painel com três tipos diferentes de regressão, sendo elas os modelos pooled, de efeitos fixos, e de efeitos aleatórios. A população do estudo consiste nas capitais do Brasil no período de 2011 a 2020, resultando em um total de 270 observações.

Resultados e Discussão: Os resultados obtidos revelaram que o PIB per capita e a proporção das despesas em relação ao PIB emergem como variáveis significativas e relevantes. Além disso, o IDH também exibiu significância positiva, sugerindo que um aumento no IDH da capital está associado, de acordo com o modelo, a um aumento nos gastos ambientais.

Implicações da Pesquisa: Analisar os determinantes dos gastos públicos destinados ao meio ambiente pode contribuir para a tomada de decisão e o desenvolvimento de melhores políticas públicas.


Palavras-chave: Gastos Ambientais, Índice de Desenvolvimento Humano, Despesas Totais, Produto Interno Bruto.

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1 INTRODUCTION

Sustainable development, which balances the need for economic growth with environmental protection, has become an important concept in recent decades, and this is seen in various spheres, from academia to political organization (Diniz et al., 2018). This concept has been driven by growing environmental awareness around the world, which reflects the recognition of the impact of human activities on the health of the planet and the sustainability of natural resources. Modern societies are increasingly improving sustainability practices, a paradigm shift that indicates the understanding that the health of the planet is intrinsically linked to human well-being (Confalonieri, 2003).

This paradigm is driven by the serious environmental problems caused by the degradation of nature that the world has faced in recent decades. The destruction of natural habitats, air and water pollution, the depletion of natural resources and the loss of biodiversity are just some of the environmental challenges that threaten life on earth. Furthermore, the global climate crisis, which is amplified by these issues, poses a significant risk to human development and economic stability across the world (Diniz et al., 2018).

Given the magnitude of these challenges, it is essential that governments and academics seek sustainable solutions to solve environmental problems. In the meantime, scientific research
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has a crucial role to play in developing more environmentally friendly technologies, improving natural resource management and promoting sustainable practices. Added to this, governments have the responsibility to promote public policies that encourage sustainable development and environmental protection (Tozato et al., 2019).

A fundamental issue within the context of environmental preservation is public spending on the environment, which Wilkinson et al. (2009) call it budget green. This term refers to the amount of resources that governments allocate to the protection and conservation of the environment in their annual budgets. The green budget has the potential to finance the transition to a greener economy and support the implementation of public policies that aim to mitigate and adapt to climate change.

There are methodologies that measure the impacts of budgetary expenditures on environmental issues, and this has been an emerging field of knowledge. Some works already seek to carry out a specific analysis between public spending, especially budgetary spending, and the impacts on the configuration of the energy matrix (Carneiro, 2008; Mcgregor et al., 2021; Sovacool et al., 2022). These methodologies, often based on environmental economics principles, allow for a more accurate assessment of the costs and benefits of environmental policies, contributing to better decision-making at public policy level.

In this way, spending on the environment becomes a parameter to measure government officials' commitment to environmental sustainability. The responsibility for collecting, processing and disseminating this data lies with accounting, which is the primary source of information for both private and public entities. Accounting must record and reveal the actions implemented and their respective results, including those related to environmental management.

Previous research (Bacot & Dawes, 1997; Lester & Lombard, 1990; Stanton & Whitehead, 1994; Konisky & Woods, 2012) identified variables that can influence public expenditure on the environment, such as: Population, GDP, HDI, Total Area, Total Expenditure, Revenue Received, Demographic Density. To do this, they used the relative environmental expenditure index, which is the proportion of environmental expenditure in relation to the total expenditure of the public entity.

From this perspective, this study questions what are the determining variables of public spending on Environmental Management in the states of Brazil during the period from 2011 to 2020? Therefore, the central objective is to analyze the determinants of public spending on environmental management in the states of Brazil in the period from 2011 to 2020. For this, the
panel data methodology is used with three types of regression, namely the models pooled, fixed effects, and random effects.

**2 THEORETICAL FOUNDATION**

**2.1 HUMAN DEVELOPMENT INDEX AND ENVIRONMENTAL EXPENDITURE**

The Human Development Index (HDI) is a measure that evaluates the levels of socioeconomic development of a country, serving as a parameter to assess quality of life (França, 2021). The HDI can be defined in three different dimensions: life expectancy, education and income level (Martins; Ferraz; Costa, 2006).

The HDI has formed the basis of the Human Development Report (HDR) since 1990, its score varies on a scale from 0 (low human development) to 1 (very high human development), providing a comprehensive measure of a country's social and economic progress. (Barbosa et al., 2015).

Guandalini's research (2016, p. 56) included the state HDI among the social variables to verify its degree of impact on environmental spending, “[...] it was expected that the higher [...] the HDI of the states, the greater the expenditure on the environment would be”. Broietti et al. (2018) carried out a survey from 2002 to 2019 with all municipalities in Brazil to identify the determinants of environmental spending in these locations, concluding that the HDI is one of the socioeconomic variables that influence these expenses. According to the authors, the municipalities in the South region were those that had the most environmental expenses.

In a more recent study, but with a shorter time frame (2013 to 2019), França (2021) identified that the southeast region had the highest level of environmental spending, concluding that this result is due to the fact that the municipalities in this region have the higher HDI, population concentration and resources.

On the other hand, Guallassi et al. (2017), when analyzing public environmental spending in the mesoregions of the State of Paraná in 2010, they found that the HDI was not significant in any of the adjusted regression models, that is, it was not relevant to explain environmental spending in the mesoregions of Paraná.
2.2 GROSS DOMESTIC PRODUCT AND ENVIRONMENTAL EXPENDITURE

Public expenditure refers to expenses incurred by the government in various sectors and activities to meet the needs of society. Public spending can be influenced by a variety of factors, which can be grouped into three categories of variables: socioeconomic, political and demographic (Fisher, 1964). Over the last three decades of the 20th century, in response to the approaches of environmental movements, environmental issues were gradually integrated into political agendas both internationally and nationally, influencing economic and political choices (Pereira & Figueiredo, 2020).

Public environmental spending serves as an indicator to assess managers' attention and commitment to preserving the environment (Broietti et al., 2018). Public environmental spending is related to the preservation and restoration of the environment. These public sector investments are conducted by entities responsible for environmental control, reforestation initiatives, surveillance of degraded areas, environmental prevention programs, waste removal in protection zones and maintenance of environmental reserves (Borinelli et al., 2011).

A pioneering study on environmental spending identified that population density, heating, mass transportation, as well as garbage collection influenced environmental spending (Sacco & Leduc, 1969). Broietti et al., (2018) explain that research on environmental spending contributes both to the transparency of government actions towards society, and to the managers themselves, as, by being aware of the evolution of spending, they can use resources more effectively. One of the most observed variables in studies on environmental spending is the Gross Domestic Product - GDP.

GDP is the sum of all productive activities in agriculture, industry and services during a given period, linked to the number of inhabitants in the country (Barbosa et al., 2015). It is one of the main parameters that evaluate economic growth, widely used as a reference point to measure and categorize the economic performance of nations (França, 2021).

GDP is related to environmental public spending since the higher the per capita income of society, the greater the concern with environmental issues tends to be (Stanton ; Whitehead, 1994). The higher the GDP per capita, the greater the environmental expenditure and, on the other hand, the lower the inequality in income distribution (GINI Index) the greater the public spending on research and development in the environmental area (Magnani, 2000).

The study by Ercolano and Romano (2018) investigated empirical models of environmental spending in European countries. The authors found that the average environmental expenditure in European Union countries in 2014 was 0.80% of GDP, with
Greece and Malta having the highest percentage, 1.60% of GDP, while Cyprus, Finland and Sweden had the lowest values, 0.30% of GDP.

In Brazil, “since 1996, all Federation Units have had state environmental policies and institutions responsible for their implementation” (Scardua & Bursztyn, 2003, p. 304), with each state having the responsibility to establish an administrative system responsible for implementation and oversight of these policies (Gallassi et al., 2017).

The decentralization of responsibility for environmental policy to states and municipalities was impacted by the 1992 United Nations Conference on Environment and Development (Rio-92). One of the fundamental documents, Agenda 21, highlighted the relevance of local power in the context of sustainable development. Therefore, there are many studies in the literature that analyze public environmental spending with a focus on municipalities and GDP is one of the main variables observed (Broietti et al., 2018; Carneiro & Souza, 2021).

Gallassi et al., (2017), explain that most of the resources allocated to environmental management in Brazilian cities are centralized in state capitals. This is due to the fact that these municipalities are more populous, face a higher incidence of environmental problems, have a higher demographic density and register a higher level of economic activity, resulting in greater resource availability (Guandalini et al., 2013).

However, the study by Carneiro and Souza (2021) found that it is not the largest municipalities that have more efficient environmental management, but the smaller municipalities. Pereira and Figueiredo (2020) concluded that although the volumes of environmental spending are the highest among Brazilian municipalities, they do not reflect their participation in relation to general municipal expenses, economic wealth (GDP) and the number of inhabitants.

Given that economic growth does not translate into advances in human development, the limitation of GDP when addressing aspects related to the well-being of the population becomes evident. In this sense, the Human Development Index (HDI) was created, introduced by the United Nations Development Program (UNDP) as a way of providing a more comprehensive view of a nation’s progress (Barbosa et al., 2015).
2.3 TOTAL EXPENDITURE AND ENVIRONMENTAL EXPENSES

The implementation of an environmental management model requires public managers to develop indicators and conduct regular analyzes to represent the interaction between private and collective interests regarding the use of natural resources (Rezende et al., 2019).

For a more efficient management of public expenses, Ordinance No. 42, in April 1999, from the Ministry of Budget and Management, made a functional classification of public expenses and standardized the allocation of resources on public expenses destined for the environment. Function 18 intended for this purpose has the following subfunctions: environmental preservation and conservation (541); environmental control (542); recovery of degraded areas (543); water resources (544); meteorology (545) (Pereira & Figueiredo Neto, 2020).

Research on environmental spending in the Brazilian public sector is relatively recent and scarce, starting after the end of the 1990s, with more exploration being done at the federal level of analysis and total expenses, by function and sub-functions of environmental management. (Borinelli et al., 2017).

Total expenditure represents the sum of all annual public expenditure, that is, it is the sum of all functions (budget expenditure committed), normally has a positive relationship with environmental expenditure (Sacco & Leduc, 1969; Lombard, 1993).

The study by Borinelli, Guandalini and Baccaro (2017) on public environmental spending found that from 2002 to 2012 Brazilian states allocated, on average, 0.53% of their total spending to the environment. The authors concluded that Ceará is one of the most prominent states in the Northeast region, with environmental expenditure exceeding 1%, possibly due to investments to overcome water scarcity problems. Another relevant result was that while the sum of the states' total expenses grew by 39% in the period, the sum of the amounts allocated by the states in the environmental management function reduced by 2%.

It is important to highlight that the relationship between total expenditure and public environmental spending may vary according to government priorities and policies. In some cases, governments may increase or decrease the allocation of resources for environmental spending based on economic, social or environmental considerations. A balanced and sustainable approach often involves ensuring that an adequate portion of total expenditure is allocated to initiatives that promote sustainability and environmental preservation (Bueno, 2013; Guandalini, 2016).
With the theoretical framework exposed, it was possible to identify the research hypotheses. Figure 1 presents the hypotheses worked on.

**Figure 1**

*Research hypotheses*

![Hypotheses Diagram]

Source: Own preparation (2023).

**3 METHODOLOGY**

This study is defined as exploratory, an approach chosen due to the lack of previous research on the elements that affect environmental investments in municipalities in southern Brazil. Collins and Hussey (2005) emphasize that exploratory research is appropriate in scenarios where there is a lack or limited amount of investigations on the topic in question.

As for the methodological structure, the research is guided by a quantitative approach, a strategy that allows, through statistical methods, to identify the factors that influence environmental spending in southern Brazilian municipalities. According to Collins and Hussey (2005, p. 24), quantitative methodology "implies the collection and analysis of numerical data, in addition to carrying out statistical tests".

The study population is the capitals of Brazil in the period from 2011 to 2020. So that the constructed Panel could remain balanced, it was decided to end the time horizon in 2020, considering that some more recent data, for some capitals, are not yet published. The result produced a total of 270 observations.

Data collection for data relating to Environmental Expenses was carried out by IpeaData, using the classification of Expenses by function and data from function 18 (expenditure on...
Environmental Management). It was decided to use data on the committed expenses of each federative entity. Data relating to GDP at market prices and Budget Revenue were also collected from the same database. It is important to highlight that, as these are monetary values, the values were corrected using the IPCA, taking December 2022 as the base period. The remaining model data were collected by the IBGE database.

Municipal environmental public spending was the dependent variable, that is, the independent variables used had socioeconomic characteristics such as: Gross Domestic Product (GDP); territorial area; demographic density; population. The following were also used as independent variables: total expenses and income received.

For data analysis, the RStudio software (R version 3.3.0) was used. For Fávero and Belfiore (2017), panel data analysis has the main advantage of separately measuring the effects generated due to differences in each observation in each cross-section, and makes it possible to analyze the evolution for each municipality in relation to the variables at hand, over time. In general terms, a linear model can be specified with panel data, as follows:

\[
gamb_{it} = \beta_0 + \beta_1 PIBp_{it} + \beta_2 area_{it} + \beta_3 dens_{it} + \beta_4 dtptib_{it} + \beta_5 rtptib_{it} + \beta_6 dttr_{it} + \beta_7 idh_{it} + u_{it}
\]  

(1)

Where:

- \( gamb_{it} \) is the dependent variable, representing the environmental expenditures incurred in the states in function 18, in the commitment phase.

The independent variables are:

- \( PIBp_{it} \) representing the Gross Domestic Product at state market prices, updated by the IPCA.
- \( area_{it}, dens_{it}, dtptib_{it}, rtptib_{it}, dttr_{it}, idh_{it} \), represent, respectively: geographic area of the state, population density, percentage of expenditure on Environmental Management in relation to GDP, percentage of Revenue collected in relation to GDP, percentage of Expense in relation to Revenue collected and Development Index Human (HDI).
- \( u_{it} \) represents the idiosyncratic error.
- \( B_0 \) is the intercept
- \( B_1, B_2, ... B_7 \) represent the coefficients related to each independent variable.
For this model, three different types of regression were performed: pooled, fixed effects, and random effects. The pooled model, or grouped effects model, according to Fávero (2017), assumes that there is no unobservable heterogeneity between municipalities, treating the data set as if it were a large cross-sectional sample. This model does not consider the possible correlation between the independent variables and the unobserved effects specific to each municipality, being useful when it is believed that all units in the panel are homogeneous.

The fixed effects model takes into account unchanged differences over time between municipalities, allowing each unit to have its own intercept. This model is suitable when it is assumed that variation between municipalities can affect or be correlated with the independent variables, offering an estimate that controls for unobserved heterogeneity that is constant over time (Gujarati, 2011).

Finally, the random effects model, according to Fávero (2017), assumes that differences between municipalities are random and not correlated with the independent variables. This model is appropriate when unobserved differences are considered to be uncorrelated with the model’s explanatory variables. The Hausman test, used in the present work, is frequently applied to choose between fixed and random effects models, based on the presence of correlations between unobserved effects and independent variables (Gujarati, 2011).

4 DATA ANALYSIS

The proportion of environmental expenditures in relation to the total budget of a public entity serves as a crucial indicator for monitoring the allocation of funds for environmental protection. According to Lester and Lombard (1990), a higher percentage of this index indicates a greater government commitment to environmental issues. Data collection for panel regression analysis generated the descriptive statistics present in Table 1.

Table 1
Statistic data description

<table>
<thead>
<tr>
<th>Variables</th>
<th>Average</th>
<th>Standard deviation</th>
<th>Median</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Mean standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Expenses</td>
<td>554,082,700</td>
<td>548,058,900</td>
<td>376,785,700</td>
<td>13,153,120</td>
<td>3,487,290</td>
<td>33,353,800</td>
</tr>
<tr>
<td>GDP Per capita</td>
<td>34,476.13</td>
<td>18,355.10</td>
<td>28,196.09</td>
<td>13,764.51</td>
<td>109,457.30</td>
<td>1,117.06</td>
</tr>
<tr>
<td>Density</td>
<td>71.06</td>
<td>107.42</td>
<td>34.46</td>
<td>1.19</td>
<td>494.15</td>
<td>6.54</td>
</tr>
<tr>
<td>Total expenditure in relation to GDP (%)</td>
<td>0.18</td>
<td>0.07</td>
<td>0.17</td>
<td>0.08</td>
<td>0.46</td>
<td>-</td>
</tr>
<tr>
<td>Total revenue in relation to GDP (%)</td>
<td>0.21</td>
<td>0.09</td>
<td>0.19</td>
<td>0.09</td>
<td>0.74</td>
<td>-</td>
</tr>
</tbody>
</table>
Analyzing the data in the table above, it is possible to see that the variation in these expenses is wide, as denoted by the standard deviation of magnitude close to the average. When observing GDP per capita, it is clear that there is a high average, accompanied by a substantial standard deviation, which suggests significant economic inequalities between capitals. Such disparities can influence the capacity to invest in the environment, where richer capitals possibly have greater environmental expenses.

Demographic density, with its high mean and standard deviation, indicates heterogeneity in population concentration between capitals, which can also impact environmental needs and priorities. Looking at total expenditure in relation to GDP, it is observed that capital cities spend, on average, 0.18% of their GDP on the environment. Although the standard deviation is low, which would indicate a certain homogeneity, the difference between the minimum and maximum values reveals that some capitals may be investing proportionally more than others. Total revenue to GDP averages 0.21%, which points to a modest portion of GDP being converted into revenue. The consistency of this value between capitals is marked by the low standard deviation. As for total expenditure in relation to total revenue, the high average of 0.87% reflects a tendency for capital cities to dedicate a large part of their revenue to expenses, including environmental ones, with little variation between them, as shown by the standard deviation.

Our hypothesis suggests that the environmental expenditures of a federative entity are representative with regard to that entity's concern with the environment. However, this study questions what influences these expenses. When running the regression on the presented models, it was obtained the results in Table 2. The table presents the value of the respective coefficients and the standard errors in parentheses.

Table 2
Panel regression results

<table>
<thead>
<tr>
<th></th>
<th>Pooled</th>
<th>Effects fixed</th>
<th>Effects Random</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDPP</td>
<td>-0.561***</td>
<td>1.848***</td>
<td>1.181***</td>
</tr>
<tr>
<td></td>
<td>(0.215)</td>
<td>(0.317)</td>
<td>(0.207)</td>
</tr>
<tr>
<td>dens</td>
<td>-0.001</td>
<td>-0.003</td>
<td>0.0005</td>
</tr>
<tr>
<td></td>
<td>(0.0005)</td>
<td>(0.016)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>dtpib</td>
<td>-1.744</td>
<td>11.338***</td>
<td>3.583**</td>
</tr>
<tr>
<td></td>
<td>(2.815)</td>
<td>(1.375)</td>
<td>(1.722)</td>
</tr>
</tbody>
</table>

Source: Elaboration own (2023).
Hausman test was applied, which is used to test the null hypothesis that the differences in coefficient estimates between fixed effects and random effects models are systematically zero. In other words, it checks whether the random effects estimators are consistent and therefore whether the random effects model is appropriate. In the presented result, the test produced a chi-square value of 379.34 with 6 degrees of freedom (df), and the extremely low p-value, which indicates that the null hypothesis of the test is rejected with a high degree of confidence.

In the results table, (*) was used to indicate the level of statistical significance of the estimated coefficients. The more asterisks, the more confident we are that the independent variable has a statistically significant effect on the dependent variable in the population. A smaller p-value indicates greater evidence against the null hypothesis (usually the hypothesis that there is no effect), and in regression models, this usually means that there is enough evidence to claim that the estimated coefficient is non-zero. Variables with ***, for example, are those that are statistically significant at the 1% level, which is strong evidence that there is a relationship between this independent variable and the dependent variable.

Thus, it is possible to infer that there is a significant difference between the estimators of the fixed effects and random effects models. This implies that the random effects model is not consistent for the analyzed data, and the fixed effects model is preferable. The result also suggests that unobserved characteristics specific to each unit (capitals, in this case) are correlated with the independent variables. This justifies the use of the fixed effects model, which controls for these unobserved characteristics.

Pooled model, which treats panel data as a large cross-sectional sample, ignoring specific differences between units over time, provides an overview of the general trends present in the data. In this regression, the coefficient of the GDPP variable, which represents the natural logarithm of GDP per capita, is significantly negative (-0.561). This result suggests that, on
average, an increase in GDP per capita is associated with a decrease in environmental spending in Brazilian capitals. This negative relationship may indicate that, as GDP per capita increases, there is greater efficiency in the management of environmental resources or a change in the composition of expenditure that favors other areas to the detriment of the environment.

The variable dens, which represents population density, did not show statistical significance ($p = 0.890$), indicating that, in this model, population density does not have a significant impact on environmental expenditure. This may suggest that factors related to population density, such as pressure on natural resources or the need for environmental services, are not the main determinants of environmental spending in Brazilian capitals, at least not in a way that is captured by this model. In turn, the dtpib and rtpib variables are also not statistically significant in this model.

On the other hand, the variable idh, which represents the Human Development Index, is significant and positive (7.631). This indicates that an increase in HDI is strongly associated with an increase in environmental spending. This result may reflect greater awareness and appreciation of the environment in areas with better human development, or it may indicate that regions with higher HDI have more resources to allocate to environmental initiatives.

In terms of model fit, the adjusted R suggests that approximately 48.9% of the variation in environmental expenditure is explained by the variables included in the model. While this value indicates a good proportion of the variance explained, it is important to note that more than half of the variance is still left unexplained, which could be due to other factors not included in the model or the simplified nature of the Pooled model.

Pooled model suggests that, in Brazilian capitals, environmental expenditures are negatively correlated with GDP per capita and positively correlated with HDI, while population density and other economic variables do not appear to have a significant impact. These results may have important implications for environmental policymaking, highlighting the need to consider economic and human development when planning and allocating resources for environmental management. However, it is crucial to remember the limitations of this model and consider the possibility that heterogeneity between capitals could influence these results.

The analysis of the fixed effects model offers a different perspective compared to the Pooled model, as the GDPC variable presents a positive and significant coefficient (1.848). This result contrasts sharply with that found in the Pooled model. It indicates that, when controlling for the unobserved and constant characteristics of each capital, an increase in GDP per capita is associated with an increase in environmental spending. This may reflect that,
within each capital, periods of greater economic prosperity are linked to an increase in resources allocated to the environment.

The variable dens is also not statistically significant. This finding reinforces the idea that other factors, in addition to population density, are more influential in determining environmental spending. However, the dtpib variable shows a positive and highly significant coefficient (11,338). This indicates that variations in the proportion between total expenditure and GDP are strongly associated with an increase in environmental spending. The significance and magnitude of this coefficient suggest that this variable captures important aspects that influence environmental spending.

On the other hand, the rtpib variable is not significant (p = 0.245), indicating that it does not have a significant impact on environmental spending. Likewise, the dtrt variable, despite being significant in the pooled model, is not significant in the fixed effects model. The variable idh, which represents the Human Development Index, is also not significant (p = 0.568).

The model's adjusted R indicates that around 35.3% of the variation in environmental spending is explained by the variables included in the model, when considering heterogeneity between capitals. In conclusion, this model reveals that, when controlling for the specific and constant characteristics of each capital, GDP per capita and the dtpib variable are significant factors in environmental spending, while population density, rtpib and hdi are not.

Finally, the analysis of the random effects model assumes that, although there is heterogeneity between capitals, this heterogeneity can be treated as a random component uncorrelated with the independent variables.

In the results of this model, the variable GDPC, which represents the logarithm, displays a positive and significant coefficient (1.181) with a very low p-value. This result is consistent with that observed in the fixed effects model and suggests that, considering the random heterogeneity between capitals, an increase in GDP per capita is associated with an increase in environmental spending. This may indicate that capitals with greater wealth tend to allocate more resources to environmental protection and management.

The variable dens, which denotes population density, is not statistically significant (p = 0.571) in this model. The dtpib variable shows a positive and significant coefficient (3.583) with a p-value of 0.044. This result reinforces the idea that economic changes over time, possibly captured by this variable, influence environmental spending. On the other hand, rtpib is significant and negative (-2.775) with a p-value of 0.035. This suggests that the proportion of total revenues to GDP has a negative influence on environmental spending.
The variable idh, which represents the Human Development Index, is significant and negative (-3.304) with a p-value of 0.017. This result contrasts with that observed in the pooled model and suggests that, when considering random heterogeneity between capitals, a higher HDI is associated with a reduction in environmental spending. The model's adjusted R indicates that around 16.6% of the variation in environmental spending is explained by the independent variables, considering the random heterogeneity between capitals. The summary of the results of this research is seen in Table 3.

**Table 3**

*Summary of results in the Fixed Effects model*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Expected outcome</th>
<th>Theoretical basis</th>
<th>Result obtained</th>
<th>Conclusion on the hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDI</td>
<td>+</td>
<td>Martins, Ferraz and Costa (2006)</td>
<td>Meaningful positive and</td>
<td>Confirmed (Hypothesis 1a)</td>
</tr>
<tr>
<td>GDP</td>
<td>+</td>
<td>Pereira and Figueiredo (2020)</td>
<td>Meaningful positive and</td>
<td>Confirmed (Hypothesis 2a)</td>
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<td>DT</td>
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<td>Rezende et al. (2019)</td>
<td>Meaningful positive and</td>
<td>Confirmed (hypothesis 3a)</td>
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Source: Authors’ own (2023).

**5 CONCLUSIONS**

When examining the different panel data regression methodologies applied in the study — pooled, first differences and random effects models — and considering the results of the Hausman test, there are significant implications for the theoretical model investigated. The Hausman test indicated a clear preference for the fixed effects model, implying that there are unobserved effects correlated with the independent variables that need to be controlled to avoid biased estimates. Therefore, the theoretical model must be structured to consider time-invariant heterogeneity between units.

It was observed that the model needs improvements, mainly in the inclusion and treatment of variables that can better explain the variability in public environmental spending. The analysis suggests that GDP per capita is a significant and relevant variable, indicating that more robust economies tend to allocate more resources to the environmental area. This finding is consistent with the economic literature and reinforces the need to consider a region's level of wealth when studying environmental spending. Furthermore, the proportion of expenditure in relation to GDP also showed a significant positive influence, reinforcing the idea that economic growth is associated with an increase in environmental spending. The HDI also showed positive
significance, implying that an increase in the capital's HDI tends, according to the model, to increase environmental spending.

On the other hand, variables such as population density and total revenue as a proportion of GDP did not prove to be significant determinants of environmental expenditure. This may be due to the specificity of the data or the existence of other variables that more adequately capture the effects they intend to measure.

To provide a broader and more meaningful picture, variables could be incorporated that reflect specific environmental policies, investments in green technology, the population's level of environmental awareness, or even indicators of environmental pressure, such as pollution levels and deforestation rates. These could offer additional insights into the determinants of environmental expenditure and contribute to the robustness of the model.

It is suggested that future studies explore the interaction between economic variables and more detailed social and environmental indicators. Investigating how changes in environmental legislation affect public spending and comparative analysis between different regions or countries can also reveal important patterns. Furthermore, longitudinal studies could examine how trends in environmental spending evolve in response to economic crises or natural disasters, offering a dynamic understanding of political and economic priorities regarding the environment.

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