Netherlands Under the Climate Lens: Unraveling Geographical Patterns in Collective Behavior

Bachelor Thesis

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Abstract

Climate change poses significant threats to economic, social, and spatial development. Understanding the influence of geographic context on responses to climate change in the Netherlands is crucial for effective policy development. This study investigates how geographical factors and regional vulnerabilities shape attitudes towards climate change in the Netherlands. Multiple Linear regression analysis with secondary data is employed to examine the relationship. Key variables include urban versus rural distinctions, regional vulnerability indices, and pro-environmental behavior (PEB). The analysis reveals that rural areas exhibit higher mean CO2 emissions despite higher scores of pro-environmental behavior, suggesting infrastructure deficiencies. Collectively, areas with higher population densities show lower levels of pro-environmental behavior, likely due to logistical, space, and bureaucratic challenges. Vulnerability factors such as economic decline, lack of infrastructure resilience, and high emissions negatively impact pro-environmental behavior. However, less infrastructure resilience in rural areas is associated with increased pro-environmental behavior. The study highlights the complex interplay between geographic context and environmental behavior. Rural areas manage higher renewable energy adoption despite infrastructural challenges, whereas urban areas face significant hurdles. These findings suggest the need for tailored climate policies that address specific vulnerabilities of urban and rural municipalities. Effective climate adaptation strategies must consider these geographic nuances to promote sustainable development and enhance pro-environmental behavior across the Netherlands.

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1. Introduction

Climate change is one of the most urgent challenges of our era, with far-reaching implications concerning economic, social, and spatial development. Among the natural disasters intensified by climate change, flooding is a leading threat, displacing millions and causing massive economic losses worldwide (*Economic Losses, Poverty & Disasters*, 2018). With both sea levels and population increasing in flood-prone areas, the impacts of flooding are expected to escalate further (*Climate Change and Its Consequences | Munich Re*, 2020).

In the Netherlands, flood risks in deltaic areas increase because of population growth, economic development, land subsidence, and climatic changes such as sea-level rise (de Moel et al., 2011). Given the potential consequences, floods are among the worst disasters that can hit the Netherlands (*Kleine Kansen, Grote Gevolgen*, z.d.). Various highly urbanized municipalities illustrate how specific geographic contexts influence the need for climate adaptive measures. For instance, the city of Rotterdam continues to navigate the dynamic relationship between the demand for new housing and its increasing vulnerability to flood risks due to climate change (*Too Risky to Build?* z.d.). Similarly, in Amsterdam, additional measures are necessary to protect the city against heat, drought, heavy rainfall, and rising sea levels. The plans initiated a few years ago to adapt Amsterdam to the impacts of climate change have proven inadequate. The city council reached this conclusion following the alarming new climate scenarios presented by the KNMI (Zoelen, 2023).

To mitigate these impacts, proactive measures and sustainable practices are essential. To combat these challenges, international institutions and national governments are working towards measures limiting these changes. The coalition agreement targets energy neutrality by 2050, with the goal being a 55% reduction in CO_2 emissions (Klimaat, 2023). The "Betrokken Bij Klimaat" report, led by former ombudsman Alex Brenninkmeijer, underscores the importance of engaging citizens through government-organized participation. The report highlights that effective climate-adaptive measurements and active citizen involvement are interlinked.

As highlighted, urban municipalities like Rotterdam and Amsterdam face unique challenges. Research shows urban residents may have better access to information, higher education levels, and more civic engagement opportunities, which can influence their pro-environmental behaviors and support for climate policies (Lucas et al., 2021). In contrast, rural residents influenced by place attachment, local cultural practices, and economic reliance on natural resources may respond differently to climate policies (Huddart-Kennedy et al., 2009). Given the examples of climate consequences in highly urbanized areas, coupled with the possible distinct behaviors toward climate change and climate change policies observed in rural versus urban areas, it raises intriguing questions about the role of geographical contexts in shaping environmental behavior and policies.

However, an obstacle to effective climate adaptive measures is the lack of public participation and a cooperative attitude towards climate change and the policies aimed at it (Lucas et al., 2021). The Dutch government struggles to engage citizens and municipalities in the energy transition due to cost issues, practical challenges, and socio-economic inequalities (Beauchampet & Walsh, 2021). The study of Rodríguez-Pose and Bartalucci (2023) extends and explains this issue further, suggesting that certain places, with certain characteristics, are more “vulnerable” and “left behind” in the transition to green energy than other places, hence causing differential perceptions and attitudes towards the green transition. The study suggests that the "places that don't matter" rather than the "people that don't matter" have reacted in response to feelings of neglect and marginalization. They suggest regions with high unemployment, economic decline, and structural weaknesses feel marginalized in the green transition. Highlighting the potential for increased discontent and social polarization. It suggests that neglecting these regions in the green transition could lead to heightened opposition, social unrest, and support for climate-change-sceptic positions, ultimately undermining the successful implementation of green policies (Rodríguez-Pose & Bartalucci, 2023).

This study will delve deeper into the problems arising of the engagement and behavior of municipalities towards the green energy transition (Beauchampet & Walsh, 2021) and the effect and characteristics of the “places that don’t matter” (Rodríguez-Pose & Bartalucci, 2023). The study will indicate if, indeed, municipalities in the Netherlands with specific characteristics of “vulnerable” places also exhibit lower levels of pro-environmental behavior. The study will assess how and if these factors influence environmental behavior at the municipal level in The Netherlands.

The existing literature has explored various aspects of pro-environmental behavior. Research by Muhammad Mehedi Masud (Masud et al., 2017), for example, highlights the importance of socio-demographic factors and tailored interventions. These do not address the specific geographic distinctions or vulnerabilities in the Netherlands and the impact this may have on environmental behavior. There is not yet a study that investigates the vulnerabilities (Rodríguez-Pose & Bartalucci, 2023) on a lower administrative municipal level in The Netherlands and if they affect the level of local government environmental behavior. This research gap is filled by examining the interaction between certain vulnerability characteristics of urban and rural municipalities in The Netherlands. It offers a multi-dimensional view specific to the municipal level of The Netherlands and distinguishes between urban and rural areas (Mittenzwei et al., 2023), linking this with the level of pro-environmental behavior by local governments.

This study tries to gain insight into how much local governments in The Netherlands engage in pro-environmental behavior and if this has a relationship with the level of vulnerability of a particular region Rodríguez-Pose and Bartalucci (2023). This study tries to discover for The Netherlands if certain “vulnerable” regions might actually exhibit lower levels of pro-environmental behavior and less “vulnerable” regions higher levels of pro-environmental behavior.

The motivation for this research lies in its potential to enhance the effectiveness of climate change policies through a nuanced understanding of geographic influences on response and behavior towards climate change. It can also create insight into which factors do or do not influence pro-environmental behavior. By focusing on vulnerable regions, this study can identify specific local concerns and challenges that policy interventions need to address. (Rodríguez-Pose & Bartalucci, 2023).

Dividing the analysis into urban and rural contexts allows for a more precise understanding of these differences. This division ensures that policies can be tailored specifically to urban and rural municipalities' unique needs and characteristics, leading to more efficient and impactful interventions. The goal is to ultimately enhance the overall effectiveness of climate change policies and aid in the need for effective climate adaptation measures in The Netherlands. To be able to provide more insight into local governments behavior towards climate change and climate change policies in The Netherlands and the different geographical context factors that may play a role, the resulting research question in this study is:

"To what extent do regional vulnerability characteristics influence pro-environmental behavior in municipalities in The Netherlands, and how do these influences differ between urban and rural areas?"

The research covers different layers and links different literature into one multi-linear analysis, leading to a more comprehensive and in-depth understanding of the existing theories.

2. Theoretical framework

To date, research has addressed a plethora of climatic issues. However, the role of public attitudes in addressing the problems associated with future climate change has only recently been acknowledged (Masud et al., 2015). Pro-environmental behavior (PEB) refers to actions taken by individuals to reduce their impact on the environment. It includes recycling, conserving energy and water, reducing waste, and supporting renewable energy initiatives (Hamelin & Bhatti, 2023). Zooming in on a more local governmental level, municipalities can play a crucial role in facilitating and promoting PEB through policy measures, community programs, and infrastructure investments. For instance, local governments can implement recycling programs, provide incentives for energy-efficient home improvements, and invest in renewable energy alternatives (Barr & Gilg, 2006; Bulkeley & Betsill, 2003). In opinion polls, renewable energy and energy-saving measures were consistently ranked as the top two strategies for mitigating climate change (Lucas et al., 2021). Municipalities have significant control over local energy policies and infrastructure investments. By supporting and increasing the share of renewable energy, municipalities demonstrate a tangible commitment to PEB (Barr & Gilg, 2016; Bulkeley & Betsill, 2010).

However, the motivations behind local government acts of PEB measures, such as renewable energy usage, can be multifaceted. Henner Busch and K. McCormick (2014) identify critical success factors and motivations for local government actions, highlighting that mayors prioritize their municipalities' well-being, including economic factors and community strengthening. This suggests that policies should emphasize the co-benefits of renewable energy, such as community cohesion and economic development, rather than focusing solely on climate change mitigation.

Focusing solely and universally on climate change mitigation as a government, Rodriquez-Pose and Bartalucci (2023) introduce the concept of “territorial discontent,” which arises when climate policies fail to address the socio-economic needs of vulnerable regions. The study delves deeper into this subject, where uneven policy outcomes contribute to social and political tensions. As for detecting a region's vulnerability, the study of Rodriquez-Pose and Bartalucci (2023) presents an analytical framework for identifying and assessing the regional impacts of the green transition and identifying the “places that don’t matter” by developing a Regional Green Transition Vulnerability Index, a combined measure of the regional vulnerability of European regions to the socio-economic reconfigurations driven by the green transition.

The study indicates vulnerability variables like structural weaknesses measured as infrastructure resilience and economic diversification. Emissions are measured as the amount of CO2 emitted per region, and economic decline is measured as unemployment rates or economic dependency on a certain region. Low infrastructure resilience, like access to public transportation, indicates a region is more vulnerable. Enhancing public transport infrastructure can significantly reduce individual car use, lower greenhouse gas emissions, and decrease urban air pollution (Rodríguez-Pose & Bartalucci, 2023). However, the rebound effect can also come into play. Meaning that improved public transport might lower transportation costs, potentially leading to an increase in overall travel demand. This could offset some environmental benefits by increasing travel and related emissions (Söderholm, 2020).

The duplicate accounts for economic diversification; for example, the share of industries per municipality indicates that a region is more vulnerable to the challenges posed by the green transition, according to Rodríguez-Pose & Bartalucci (2023), but here, the rebound effect can also play part (Söderholm, 2020). Regions with high emissions are considered more vulnerable to the green transition because high emissions indicate a greater reliance on polluting sources of energy and industries, making the region more exposed to the negative impacts of transitioning to a low-carbon economy. Regions with economic decline, like high unemployment rates, are also considered more vulnerable (Rodríguez-Pose & Bartalucci, 2023). This is aligned with Meyer’s (2015) findings, stating that economic hardship often leads to lower engagement in pro-environmental behavior.

The study of Klaus Mittenzwei (2023) suggests that there may also be a rural-urban divide in perceptions of climate policy and its impact on agriculture and rural areas. It mentions that rural citizens, in general, are less likely to be in favor of climate policies compared to urban residents. Other research suggests that urban residents may have better access to information, higher education levels, and more civic engagement opportunities, which can influence their pro-environmental behaviors and support climate policies (Lucas et al., 2021). In rural areas, factors like place attachment, local cultural practices, and economic reliance on natural resources can shape climate adaptive behaviors differently. Rural residents might be more directly impacted by climate changes in their daily lives, influencing their perception and responsiveness to climate policies (Huddart-Kennedy et al., 2009).

In the Netherlands, regional land use and mobility policies can influence travel behavior significantly. With active spatial planning promoting sustainable transport, urban areas show higher PEB. In contrast, rural areas with less infrastructure for alternative transportation may rely more on cars, demonstrating lower PEB (De Vos, 2015). However, a different study suggests rural areas may have a stronger connection to nature and different socio-economic challenges compared to urban areas, affecting their pro-environmental behaviors (Duron-Ramos et al., 2020). The publication: "Climate Change and Energy Transition: Views and Behavior of Dutch Citizens in 2021" focuses on what residents of the Netherlands think and do in relation to climate change. This report stated that people from urban areas generally act and think, on most proposed themes, more climate-conscious than rural residents (Statistiek, 2021), except for the number of flights they took; here, the citizens from urban areas scored higher.

In terms of vulnerability of rural and urban areas some literature states that regions with high infrastructure development and low agricultural dependence are less vulnerable. Densely populated areas with high reliance on agriculture and emissions are highly vulnerable (Gbetibouo et al., 2010), using indicators such as adaptive capacity, infrastructure development and land degradation. Another study suggests urban areas are least vulnerable, while rural mountain zones are most vulnerable due to low adaptive capacity and high exposure (Heltberg & Bonch-Osmolovskiy, 2011).

Regions with well-developed public transport systems often see higher rates of renewable energy adoption. This is partly because efficient public transport reduces the overall demand for fossil fuels, making it easier for renewable energy sources to meet energy needs. Furthermore, integrated transport and energy policies can enhance the infrastructure for renewable energy projects, such as solar panels on transport stations or wind energy integration with rail systems (Frontiers in Environmental Science, 2023). One significant contradiction can be that expanding public transport infrastructure, especially in densely populated regions like the Netherlands, can limit the available space for renewable energy installations such as solar and wind farms. Urban areas often face space constraints, and prioritizing land for public transport infrastructure can reduce the availability of suitable sites for large-scale renewable energy projects (CMS Expert Guides, 2023).

Building on this extensive body of literature, this research will utilize a Multiple Linear Regression analysis on various vulnerability indicators identified by Rodríguez-Pose and Bartalucci (2023) -such as CO2 emissions, economic activity, and structural weaknesses- this study will assess the impact of these factors on the share of renewable energy in each municipality. Instead of focusing on the European regional level, this study will delve deeper into a lower administrative level in the Netherlands, specifically the municipal level. The distinction between urban and rural municipalities will allow for a nuanced comparison of how geographic context shapes the relationship between regional vulnerability and PEB. This approach will provide insights into whether policies must be tailored differently for urban and rural areas to effectively address their specific vulnerabilities that affect pro-environmental behavior.

2.1 Hypotheses/expectations

Based on the findings of the literature above and the chosen indicators of research, expectations are that there is a significant difference in pro-environmental behavior (PEB) between urban and rural settlements in the Netherlands. Moreover, given the information from the survey data of CBS (Statistiek, 2021), suspicions are that very urban municipalities will exhibit higher levels of pro-environmental behavior. Regions with higher vulnerability indices, as indicated by Rodriquez-Pose and Bartalucci (2023), will show lower levels of pro-environmental behavior compared to regions with lower vulnerability indices. Dividing these specific vulnerability indicators, the hypotheses are:

- There is a negative relationship between the average distance to public transport and (PEB) in a municipality. This implies that greater distances to public transport (indicating lower infrastructure resilience) will be associated with lower PEB
- There is a positive relationship between the number of economic activities and (PEB) in a municipality. This implies that higher economic diversification (indicating stronger economic resilience) will be associated with higher PEB
- High CO_2 emissions indicate higher vulnerability due to higher pollution levels. Thus, the hypothesis is that higher CO_2 emissions would be associated with lower pro-environmental behavior (PEB)
- A high unemployment rate suggests higher vulnerability due to economic instability. Thus, the hypothesis is that higher unemployment rates would be associated with lower PEB.

3. Methodology

This study will perform quantitative research and involves a multifaceted approach, integrating literature reviews and secondary data analysis. In this study, the dependent variable under investigation is the behavior toward climate change, which is specified as pro-environmental behavior (PEB) (Hamelin & Bhatti, 2023). The independent variables are the vulnerability indicators of various regions in the Netherlands, as indicated by the vulnerability index proposed by Rodguez-Pose and Baralucci (2023). The study tries to test the effect of these independent variables to observe potential associations with communal attitudes towards climate change and what this means for climate change policies. Because of the significant differences in rural and urban settlements in The Netherlands (Mittenzwei et al., 2023), these will be separated into two datasets in order to accurately compare the effects of certain vulnerability factors (Rodríguez-Pose & Bartalucci, 2023). This results in the conceptual model visualized in Figure 1: Conceptual model.

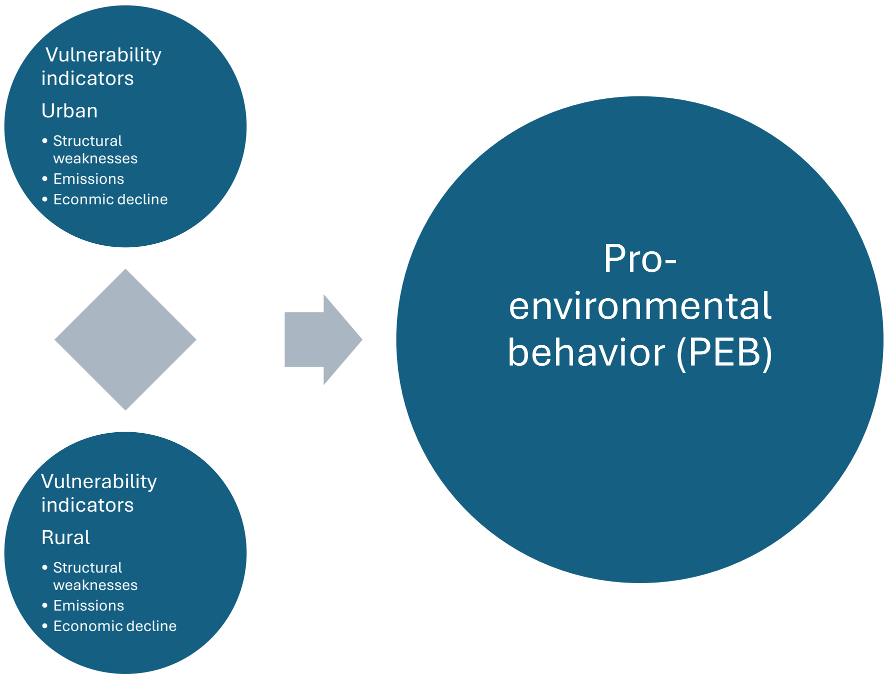

Figure 1: Conceptual model

3.1 Data collection

Most data, including urbanization degree, unemployment rates, and infrastructure resilience, is derived from the CBS Open Data StatLine platform, which provides extensive statistical information about the Dutch economy, society, and environment. Data on CO2 emissions, economic activity, and renewable energy usage is sourced from "waarstaatjegemeente.nl". Additionally, the CBS publication "Climate Change and Energy Transition: Views and Behavior of Dutch People in 2020" has been used to interpret regression results, focusing on residents' attitudes and actions regarding climate change. Pro-environmental behavior (PEB) is measured by the percentage of renewable energy (electricity, heat, and energy in transport) per municipality, based on 2023 data from CBS and RVO datasets. A more in-depth explanation of the databases utilized and the variables chosen can be found in Appendix A.

3.2 Variables and measures

The rationale behind the chosen dependent and independent is explained in this section. To ensure the validity of the findings, several control variables are included in the regression analysis. These control variables help to account for other factors that might influence pro-environmental behavior, ensuring that the observed effects are primarily due to the main independent variables. The choice of variables is guided by their theoretical and empirical relevance to the research question. Table 3 in Appendix A shows in more detail which variables are used. The variables selected for the regression analysis, along with their definitions, are as follows:

3.2.1 Pro-environmental behavior (PEB) – dependent

In this study, the share of renewable energy generated and used per municipality in the Netherlands is utilized as an indicator of PEB. This choice is supported by the notion that higher adoption of renewable energy sources reflects a collective commitment to sustainable practices. Using the share of renewable energy as an indicator for PEB for municipalities has several reasons. It provides a quantifiable measure that can be readily obtained from available data sources, ensuring consistency and comparability across municipalities. The share of renewable energy often reflects the success of local and national policies promoting sustainable energy sources (Barr & Gilg, 2006; Bulkeley & Betsill, 2003). The percentage of renewable energy can be measured and compared relatively easily and objectively between municipalities, making it a reliable and consistent measure (Hamelin & Bhatti, 2023).

3.2.2 Independent variables

The full description and rationale behind all the chosen independent variables and their measurement can be found in Appendix E.

Urban versus rural

In CBS statistics for the Netherlands, municipalities are classified as urban if they have a population density of more than 1,500 inhabitants per square kilometer and rural if the density is lower than this threshold. This classification aligns with CBS definitions and is based on address density in grid squares of 500 by 500 meters (Statistiek, 2023)

Structural weaknesses

It is divided into two variables, each accounting for an aspect of the structural weakness of a region. One is infrastructure resilience, and one is economic diversification

- **Infrastructure resilience**

Measured by the average distance to a train station per municipality, indicating the accessibility and connectivity of the region (Rodríguez-Pose & Bartalucci, 2023)

- **Economic diversification**

Measured by the share of industries in a municipality, reflecting a region's economic base and its ability to withstand economic downturns (Rodríguez-Pose & Bartalucci, 2023)

Emissions

Calculated using energy carriers and their emission factors, indicating a region's reliance on polluting energy sources and its vulnerability to the green transition (Rodríguez-Pose & Bartalucci, 2023)

Economic decline

This is indicated by high unemployment rates, representing economic instability and reduced resilience to economic changes (Rodríguez-Pose & Bartalucci, 2023)

3.2.3 Control variables

To isolate the effect of vulnerability indicators (independent variables), this study also controls for several factors that have been shown to influence pro-environmental behavior in the literature. These include population density, education, and income (Mehmood et al., 2022; Yousaf Raza et al., 2023). Controlling for these variables ensures that the observed effects of the primary independent variables on pro-environmental behavior (PEB) are not confounded by these socio-economic factors. This helps isolate the specific impact of regional vulnerability on renewable energy adoption. Their rationale and the way that they are measured are further described in Appendix E.

3.3 Analytic approach

This approach results in the following two MLR formulas for rural and urban municipalities in the Netherlands.

Regression formula urban:

$$\mathrm{PEB}_{\mathrm{Urban}} = \beta_0 + \beta_1(\mathrm{Infrastructure\ Resilience}) + \beta_2(\mathrm{Economic\ Diversification}) + \beta_3(\mathrm{Emissions}) + \beta_4(\mathrm{Economic\ Decline}) + \beta_5(\log(\mathrm{Income})) + \beta_6(\mathrm{Population\ Density}) + \epsilon$$

Regression formula rural:

$$\mathrm{PEB}_{\mathrm{Rural}} = \beta_0 + \beta_1(\mathrm{Infrastructure\ Resilience}) + \beta_2(\mathrm{Economic\ Diversification}) + \beta_3(\mathrm{Emissions}) + \beta_4(\mathrm{Economic\ Decline}) + \beta_5(\log(\mathrm{Income})) + \beta_6(\mathrm{Population\ Density}) + \epsilon$$

Explanation:

- β_0: Intercept term.
- $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$: Coefficients for each independent and control variable.
- ϵ: Error term.
- $\mathrm{PEB}_{\mathrm{Urban}}$: Pro-environmental behavior in urban municipalities.
- $\mathrm{PEB}_{\mathrm{Rural}}$: Pro-environmental behavior in rural municipalities.
- $\log(\mathrm{Income})$: Log-transformed income variable to address skewness.

In this study, a multiple linear regression analysis is employed to investigate the extent to which and if the vulnerability indicators above influence pro-environmental behavior (PEB), measured as the share of renewable energy per municipality. This method allows the inclusion of multiple independent variables in a single model, thereby controlling for various factors that might influence PEB simultaneously.

Before conducting the multiple linear regression, a Pearson correlation matrix is performed to detect any correlating variables. This step is crucial as it helps identify multicollinearity issues, which occur when independent variables are highly correlated with each other. High multicollinearity can distort the regression coefficients, making it difficult to determine the individual effect of each predictor. Examining the correlation matrix ensures that the variables included in the regression model are appropriate and do not exhibit problematic levels of multicollinearity. A more detailed description of the correlation matrix and the interpretation is provided in Appendix C. This approach helps to accurately capture the distinct factors influencing pro-environmental behavior (PEB).

4 Findings

The descriptive statistics for both urban and rural are included in Appendix B, table 4, and Table 5. After controlling for the missing values, 74 urban and l84 rural municipalities are included in the regression. Before performing the MLR, a correlation matrix is created for all variables to identify possible multicollinearity and gain initial insights into the relationships of the variables. Interpreting these possible relationships ensures the regression model is robust and reliable. This Pearson correlation matrix is included in Table 6 and Table 7 in Appendix C. All correlations are moderate and fall well below the threshold of 0.9, which is typically used as a red flag for multicollinearity (Frost, 2018)

4.1 Summary statistics

Urban

Analyzing the descriptive statistics in Appendix B, table 4, the high skewness in CO2 emissions and the number of highly educated people suggests that certain municipalities have extreme values, which might affect their renewable energy adoption and overall PEB. The extreme values of highly educated people in certain municipalities can be partially explained by the fact that some municipalities highly urbanized municipalities benefit from the clustering of businesses and industries, creating numerous high-skill job opportunities that attract highly educated individuals (Glaeser, 1999). Bigger cities also have many higher education institutions, attracting students who often remain in the areas post-graduation to pursue careers (Florida, 2002).

Rural

Most variables in the rural dataset exhibit moderate variability, as indicated by slightly higher skewness and kurtosis values. Specifically, the variables for the average distance to public transport, unemployment percentage, and highly educated people show positive skewness and higher kurtosis, suggesting a distribution where most municipalities have moderate values, but a few have significantly higher values. This means there might be some big differences overall per municipality in The Netherlands.
The correlation matrix in Appendix C table 7 shows, just as with urban municipalities, a few moderately strong correlations.

4.2 MLR results

Urban

The ANOVA table, which is shown in Table 9 in Appendix D, shows that the overall regression model is statistically significant ($p < 0.05$), suggesting that the independent variables together predict the dependent variable. Studying the determinants of the share of renewable energy per municipality in The Netherlands in general, for urban municipalities, 10.5% can be explained by the set of independent variables studied in this research.
The coefficients table, also visualized in Table 1 and Figure 2, shows that as the distance to public transport increases, the share of renewable energy slightly decreases. This is in line with the study of Rodriquez and Bartalucci (2023). suggesting that these areas lack the necessary support systems to effectively implement and sustain renewable energy projects in order to enhance their pro-environmental behavior. However, this relationship is not statistically significant, meaning no confident meaningful effect can be stated. The negative coefficients of the amount of CO2 emissions (with an almost significance of 0.052) suggest that higher CO2 emissions are associated with a lower share of renewable energy usage per total use of energy in urban municipalities. This aligns with existing literature suggesting that these regions are often more reliant on traditional, carbon-intensive energy sources. The same research suggests that socio-economic challenges and existing infrastructure dependencies make the transition to renewable energy more difficult in high-emission areas (Mehmood et al., 2022), which Rodríguez-Pose & Bartalucci's (2023) framework complements. In this research, when the

unemployment rates rise, the share of renewable energy usage decreases, as aligned with Rodríguez-Pose & Bartalucci (2023); this can be due to financially constrained regions prioritizing immediate economic concerns over long-term environmental investments. The outcome is not statistically significant.

Most of the variables show a weak negative relationship towards a share of renewable energy, aligning with the suggestions made in Rodríguez-Pose & Bartalucci's (2023) study.
There is an exception for the population density and the number of highly educated people. Population density shows a moderately significant negative relationship, indicating that the more populated an urban municipality is, the share of renewable energy usage decreases, and the more highly educated people in an area, the higher the share of renewable energy usage, showing a significant moderate positive relationship. The coefficient of -7.632 euro average income per month suggests that a one-unit increase in income is accompanied by a decrease in the share of renewable energy. This is an interesting finding, but because the p-value is 0.288 and the standard error is also large, there is insufficient evidence to conclude that this relationship is significant for the population of all urban municipalities in the Netherlands.

Model Urban	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
(Constant)	68.722	30.268		2.27	0.026		
Average distance to public transport	-0.196	0.197	-0.123	-0.995	0.323	0.806	1.24
Branches	0	0.003	-0.017	-0.082	0.935	0.285	3.508
CO2emissions	-2.911	1.469	-0.255	-1.981	0.052	0.743	1.346
UnemploymentPercentage	-2.248	1.421	-0.292	-1.582	0.119	0.36	2.779
LOG_Income	-7.632	7.122	-0.209	-1.072	0.288	0.323	3.1
Highly educated people	3.96E-05	0	0.448	2.608	0.011	0.416	2.405
Inhabitants per km2	-0.001	0	-0.356	-2.67	0.01	0.691	1.448

Table 1: Coefficient Model Urban (SPSS)

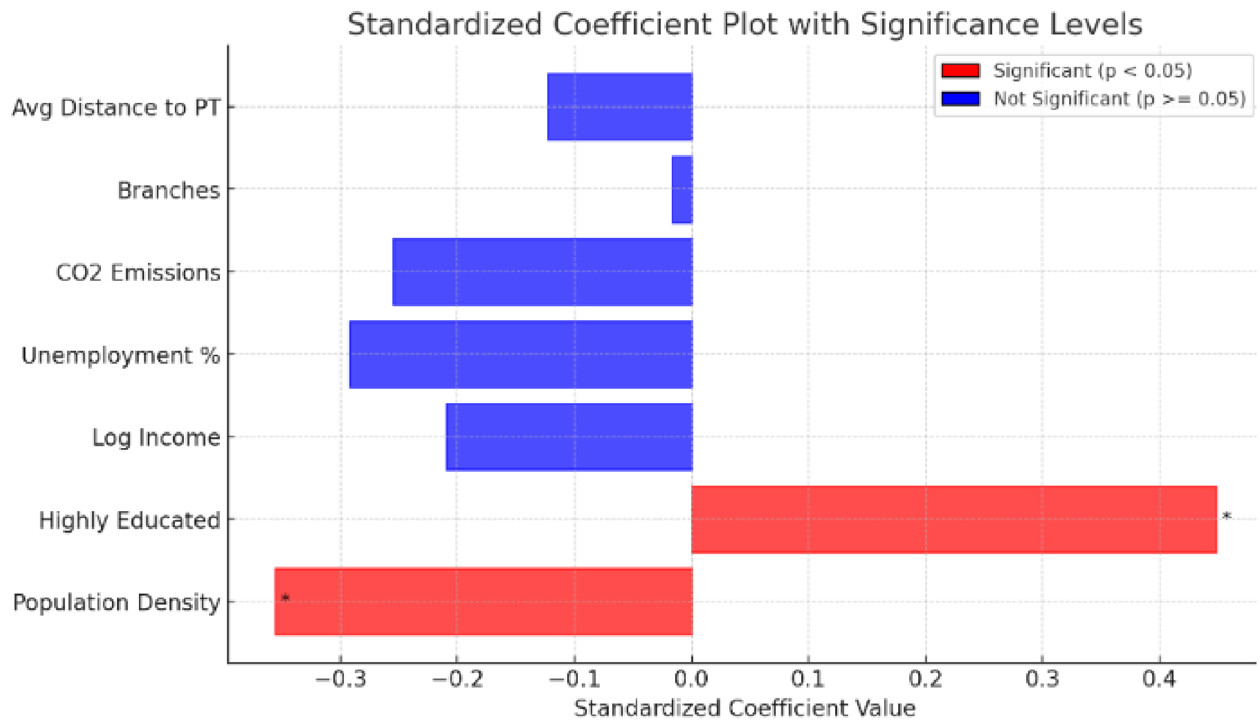

Figure 2: Standardized Coefficient Plot - Urban

Rural

The ANOVA table, which is shown in Table 11 in Appendix D, shows that the overall regression model is also statistically significant as a whole ($p < 0.05$), suggesting that the independent variables together predict the dependent variable. Studying the determinants of the share of renewable energy per municipality in The Netherlands in general, for rural municipalities, 14.5% can be explained by the set of independent variables studied in this research, slightly more than with urban municipalities.

Surprisingly, the coefficients table, which is also visualized below in Table 2 and figure 3, shows a marginally almost significant positive association. Suggesting that greater distances to public transport are associated with a higher share of renewable energy. The study of Beauchampet, I., & Walsh, B. (2021) might provide a possible explanation for this, indicating that areas with less accessible public transport infrastructure might compensate by adopting renewable energy solutions. This compensation is driven by the need to find local and decentralized energy sources that can reduce reliance on traditional infrastructure. Also, these regions may turn to renewable energy as a means to offset the lack of other infrastructural resources. This contradicts the expectation of higher discontent in vulnerable regions and poorer adaptation in terms of implementing climate policies, as was suggested in the study of (Rodríguez-Pose & Bartalucci (2023). The number of branches does not significantly predict the share of renewable energy in rural municipalities.

Although not statistically significant, higher CO2 emissions and unemployment rates are also associated with a lower share of renewable energy, just like with urban municipalities, but the relationship is very weak in rural municipalities. As for income, a significant negative relationship indicates that higher income levels are associated with a lower share of renewable energy in rural municipalities. This contradicts the findings of Perry Sadorsky (2009), whose findings indicate that increases in income have a positive impact on pro-environmental behavior. Wealthier regions have the financial resources to support the adoption of renewable energy technologies due to the higher initial capital investment required. It does align with the findings of Busch & McCormick (2014), who state that in wealthier municipalities, there is often a higher focus on economic stability and growth, which may lead to less investment in renewable energy if it is perceived as economically disadvantageous. The number of highly educated people does not significantly predict the share of renewable energy in rural municipalities. In terms of population density, a significant moderately negative relationship indicates that higher population density is associated with a lower share of renewable energy in rural municipalities, as with urban municipalities.

Model Rural	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
(Constant)	8.65	2.35		3.68	0.001		
Average distance to public transport	0.011	0.006	0.148	1.948	0.053	0.805	1.243
Branches	1.99E-05	0	0.007	0.077	0.939	0.505	1.98
CO2emissions	-0.152	0.121	-0.093	-1.254	0.211	0.841	1.189
UnemploymentPercentage	-0.187	0.177	-0.083	-1.058	0.292	0.762	1.313
LOG_Income	-1.224	0.525	-0.231	-2.332	0.021	0.477	2.098
Highly educated people	1.17E-05	0	0.068	0.89	0.375	0.808	1.237
Inhabitants per km2	0	0	-0.275	-3.42	0.001	0.724	1.382

Table 2: Coefficient Model Rural (SPSS)

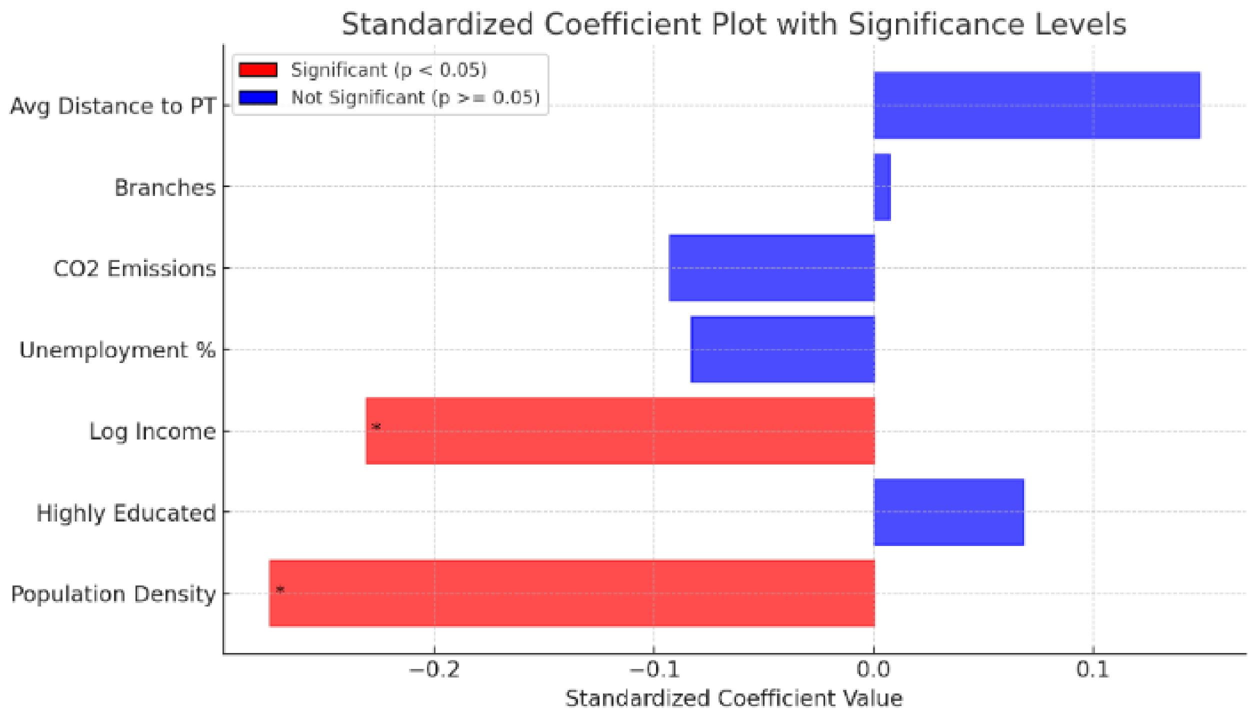

Figure 3: Standardized Coefficient Plot - Rural

4.3 Comparative analysis

As for the descriptive statistics of both urban and rural, it can be stated that rural areas have a significantly higher mean distance to public transport compared to urban areas, indicating better infrastructure in urban settings (*City-integrated renewable energy for urban sustainability | Science*, z.d.). Rural areas show slightly higher mean CO2 emissions, according to Busch and McCormick (2014), while rural areas often utilize a bigger share of renewable energy, as can be seen in the mean differences in the share of renewable energy in the descriptive statistics Table 5 in Appendix B. This can be due to different energy usage patterns and less efficient energy infrastructure compared to urban areas (Busch & McCormick, 2014), as the higher mean distance to public transport in Table 5 Appendix B confirms. Urban areas have a higher mean unemployment percentage than rural areas, indicating different economic dynamics. Data from CBS Statline indicate that this is due to rural areas having more stable employment in agriculture and local industries (*CBS Open data StatLine*, z.d.). Rural areas have higher income levels but also exhibit greater skewness and kurtosis, indicating variability and outliers. Urban areas have a significantly higher number of highly educated people but with high variability, as indicated by the skewness and kurtosis. This can be explained by the fact that most universities are located in urban areas, and in general, the population density in urban areas is higher (Lucas et al., 2021). Lastly, rural areas have a higher mean share of renewable energy, suggesting different adoption rates of renewable technologies. The case studies in Brandenburg, Germany, analyzed by Busch and McCormick (2014), highlight how rural areas are leading in renewable energy adoption due to the availability of space and resources for renewable energy projects such as wind and solar farms. But the overall higher demand for energy in urban areas, because of higher population density, should also be taken into consideration.

Analyzing the differences and similarities in coefficients and the overall model, in both urban and rural municipalities, most of the variables show a weak negative relationship towards share of renewable energy, aligning with the suggestions made in the study of Rodríguez-Pose & Bartalucci (2023). Important to note is that in urban areas, higher infrastructure resilience also indicates better renewable energy usage, although the result is not significant. But for rural areas, greater infrastructure resilience (so less average distance to public transport) does not correlate with higher renewable energy adaptation; this almost significant relationship seems reversed, indicating a different dynamic compared to urban areas. In terms of control variables, in both areas, a higher population density accounts for a lesser share in renewable energy adoption. Also surprisingly, in both areas, as income increases in an area, the share of renewable energy decreases, which is significant in rural areas. This finding contradicts Sadorsky (2009) but aligns with Busch & McCormick (2014) and Mehmood et al. (2022), indicating economic priorities might reduce investment in renewables. As for the number of highly educated people, both the outputs for the municipalities indicate a positive association, meaning the more highly educated people there are, the higher the adoption of renewable energy is, especially true in urban municipalities, according to figure 2. Significant negative association in both urban and rural areas, indicating that higher population density is associated with lower shares of renewable energy in both settings.

5 Conclusions

Referring back to the research question rural areas exhibit higher mean CO2 emissions despite having higher shares of renewable energy, as shown in Appendix B, Tables 4 and 5. This paradox can be attributed to different energy usage patterns and less efficient infrastructure in rural settings (Pamukcu-Albers et al., 2021). The complexity arises from the interconnection between these variables; specifically, the lack of infrastructure may contribute to the higher CO2 emissions observed in rural areas despite their significantly greater adoption of renewable energy sources. This suggests that infrastructure deficiencies play a crucial role in influencing CO2 emission levels (Pamukcu-Albers et al., 2021), highlighting the need for comprehensive strategies that address both renewable energy adoption and infrastructure development in rural municipalities.

Notably, rural areas have almost double the quantity of renewable energy adoption compared to urban areas. This also aligns with the findings of Busch & McCormick (2014), who suggest that this is likely due to the availability of space and resources for renewable energy projects. Additionally, the study finds that rural areas show a positive (almost significant) relationship with less infrastructure, further supporting the notion that they seem to be more invested in renewable energy. These findings highlight that rural areas, despite their infrastructural challenges, manage to compensate with higher renewable energy adoption. This suggests a complex interplay of factors where rural areas leverage their available resources to enhance their pro-environmental behavior, while urban areas face different sets of challenges due to higher population densities and logistical complexities (Mittenzwei et al., 2023). This can indicate that different climate adaptation spatial measures are needed for urban and rural municipalities in The Netherlands.

Together, the independent variables significantly influence pro-environmental behavior in a small portion of the population. Summarized, higher vulnerability factors like economic decline, less infrastructure resilience, and high emissions show a negative impact on the share of renewable energy in municipalities, although most of these associations are not significant. However, the notable exception is that in rural municipalities, less infrastructure resilience is associated with a rise in the share of renewable energy. This complex observation suggests that other underlying factors may contribute to this positive association, as the study of Busch and McCormick (2014) suggests. Further research is necessary to understand these dynamics. These findings underscore the multifaceted nature of pro-environmental behavior. Targeted climate policies can mitigate the negative impacts of these vulnerabilities, promoting sustainable development and higher PEB across municipalities. This approach aligns with the findings of Rodríguez-Pose and Bartalucci (2023), emphasizing the importance of addressing regional vulnerabilities to support the energy transition effectively.

There is a significant joint impact indicating that denser municipalities exhibit lower levels of pro-environmental behavior. The study of Beauchampet and Walsh (2021) explains this further, suggesting the complexities of public engagement. Higher population density in urban areas may lead to greater challenges in achieving consensus and mobilizing collective action for renewable energy projects. Urban environments might face more significant bureaucratic and logistical hurdles compared to rural areas. The study of Busch & McCormick (2014) found that rural municipalities might find it easier due to less regulatory complexity. However, more research that captures more significant indicators to measure pro-environmental behavior is needed to make indefinite assumptions about this. There is also the notion, which may partly explain the higher renewable energy usage in rural areas, that a higher population means higher energy demand, making it harder to rely solely on renewable energy sources.

Rural areas exhibit, in general, higher renewable energy adoption rates despite the vulnerabilities, likely due to the availability of space and resources for renewable energy projects (Busch & McCormick, 2014). This notion can be supported by the fact that rural areas also have a positive (almost significant) relationship with less infrastructure, causing higher pro-environmental behavior. To summarize, urban areas benefit significantly from higher education levels and developed infrastructure, but face challenges related to population density and economic diversity. Rural areas, while potentially having greater space and potential for renewable energy projects, can be constrained by economic priorities, and lower educational impact on environmental behavior. Although largely exhibiting the same behavior, the reasons behind it can differentiate and are more complex. Further research is needed to explain and test the "places that don't matter" theory of Rodríguez-Pose & Bartalucci (2023) and to see if vulnerable places indeed show different attitudes towards climate change and climate change policies.

6 Discussion

While the share of renewable energy is a valuable measure of pro-environmental behavior (PEB), it has several limitations. PEB includes a wide range of activities such as recycling, water conservation, and sustainable transport choices. The share of renewable energy itself can also be influenced by external factors such as the availability of natural resources and technological advancements in different areas. For example, rural municipalities near the sea are geographically more favorable for installing wind turbines. The method used by CBS is based on provincial data extrapolated to the municipal level, potentially leading to inaccuracies and generalizations that may not fully represent the actual situation at the municipal level.

In terms of the measurement of the vulnerability of regions, the economic decline can be influenced by numerous external factors, such as global market trends and regional economic policies, that may not be captured in this study (Rodríguez-Pose & Bartalucci, 2023). Measuring infrastructure resilience is challenging due to the lack of standardized metrics and the dynamic nature of infrastructure development and degradation (Pamukcu-Albers et al., 2021). Also, infrastructure is a broader concept than just measuring the distance to public transport. High emissions can result from various sources beyond municipal control, such as industrial activities and transportation policies at the national level (Busch & McCormick, 2014).

Future research should consider additional indicators of PEB. Moreover, incorporating survey-based analyses to understand the drivers of PEB would provide a more comprehensive view of pro-environmental behavior at the municipal level, mitigating the limitations of using only the share of renewable energy. Leading to a more robust and explanatory model. Analyzing survey data would also account for individual levels of pro-environmental behavior instead of collective municipal level.

Appendix A: Variable information

Variable	Definition	Coding
Dependent **Pro-environmental Behavior (PEB)**	Actions taken by individuals to reduce their impact on the environment.	The continuous variable represents the natural logarithmic percentage of renewable energy generated compared to total energy use per municipality.
Urban vs Rural	Municipalities with a high population density (more than 1,500 inhabitants per km2) are urban, and below this threshold is rural.	1 for urban (above 1,500 addresses per km2), 0 for rural (below 1,500 addresses per km2).
Independent **Infrastructure Resilience**	The capacity of infrastructure networks to continue functioning effectively. Measured by the average distance to a train station per municipality.	Continuous variable representing the average distance in km to the nearest train station.
Economic Diversification	Expanding a region's economic base by incorporating a variety of industries and sectors. Measured by the share of industries in a municipality.	Continuous variable representing the number of businesses per 10,000 inhabitants.
Emissions	The amount of CO2 emissions from various sources is calculated by multiplying energy carriers by their emission factor.	Continuous variable representing the natural logarithmic of CO2 emissions in tons per 1,000 inhabitants.
Economic Decline	Reduction in economic activity is characterized by factors such as low GDP and high unemployment. Measured by the unemployment rate.	Continuous variable representing the unemployment rate as a percentage of the total labor force.
Control variables **Income**	The average income per capita per municipality.	Continuous variable representing the natural logarithm of the average household income per month per municipality.

Population Density	The number of inhabitants per square kilometer per municipality.	Continuous variable as the number of inhabitants per km2
Education level	The number of highly educated people per municipality	Continuous variable of the number of highly educated people per municipality

Table 3: Variable Information

Most of the data, like urbanization degree, unemployment rates, and infrastructure resilience on a municipal level for The Netherlands, is derived from the OpenDataStatline of CBS. CBS Open Data StatLine is a data platform provided by Statistics Netherlands (CBS). It offers access to a wide range of statistical information about the Dutch economy, society, and environment (*CBS Open data StatLine*, z.d.).

CO2 emissions, economic activity, and renewable energy usage, are derived from datasets of "waarstaatjegemeente.nl." This platform offers a wide range of data about Dutch municipalities and is intended to provide citizens, civil servants, and policymakers with insight into all kinds of statistics and performance of municipalities (*Home - Waarstaatjegemeente.nl - cijfers en statistieken van gemeenten*, z.d.).

Furthermore, a CBS publication, "Climate change and energy transition: views and behavior of Dutch people in 2020," has been studied. This publication focuses on what residents of the Netherlands think and do in relation to climate change and the energy transition, based on survey data encompassing a wide range of themes aligning with climate change and behavior towards climate change policies (Statistiek, 2021). This can be used to better interpret the results of the regression.

The following principles have been used to determine Pro-environmental behavior (PEB) measured as the renewable electricity, heat, and energy per municipality. CBS publishes renewable heat, electricity, and energy for transport from biogas per province on behalf of RVO and the provinces. This is the total of the five techniques consisting of renewable energy, heat, and green gas per WWTP from the Union of Waterboards and Waternet. This is used to determine the renewable electricity, heat, and energy in transport from WWTP and landfill gas per municipality. It concerns the percentage share of renewable energy compared to the total energy use in the municipality. Every dataset obtained contains data from the year 2023.

Appendix B: Descriptive Statistics

Descriptive Statistics Urban	N Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Deviation Statistic	Skewness Statistic	Kurtosis Statistic
Average distance to public transport	91	1	14,1	3,362	2,3977	2,256	5,577
Branches	91	805	2349	1323,89	237,625	1,173	3,303
CO2emissions	78	7,55	9,43	8,1238	0,35591	1,54	3,029
UnemploymentPercentage	91	2,8	5,3	3,587	0,4936	0,964	1,166
LOG_Income	91	3,43	3,99	3,6281	0,10603	1,02	1,761
Highly educated people	91	3010	337200	25601,21	41224,6	5,532	37,641
Inhabitants per km2	89	384	5816	2116,7	1275,03	0,96	0,268
Shareofrenewableenergy	80	2,3	30,7	7,222	4,4195	2,98	11,728
Valid N (listwise)	74						

Table 4: Descriptive Statistics Urban

Descriptive Statistics Rural	N Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Deviation Statistic	Skewness Statistic	Kurtosis Statistic
Average distance to public transport	228	1,1	50,7	8,079	7,8413	2,657	8,861
Branches	239	782	2562	1337,49	231,874	1,133	3,791
CO2emissions	200	7,78	9,83	8,4016	0,35267	1,43	3,058
UnemploymentPercentage	239	2,4	4,6	2,929	0,2854	1,564	5,02
LOG_Income	236	3,43	4,3	3,6639	0,11023	2,408	11,707
Highly educated people	238	160	19070	5641,81	3259,586	1,288	2,328
Inhabitants per km2	239	23	2155	442,85	359,313	1,875	3,897
Shareofrenewableenergy	207	2,1	120,3	12,490	11,8315	4,952	35,616
Valid N (listwise)	184						

Table 5: Descriptive Statistics Rural

Appendix C: Pearson Correlation

Urban	Average distance to public transport	Branches	CO2emissions	Unemployment Percentage	LOG_Income	Inhabitants per km2	Highly educated people	Share of renewable energy
Average distance to public transport	1.000	-0.266	-0.105	-0.230	0.082	-0.145	-0.143	-0.048
Branches	-0.266	1.000	0.010	0.255	0.500	0.225	0.580	-0.033
CO2emissions	-0.105	0.010	1.000	0.191	-0.263	-0.370	0.128	-0.093
Unemployment Percentage	-0.230	0.255	0.191	1.000	-0.490	0.285	0.588	-0.043
LOG_Income	0.082	0.500	-0.263	-0.490	1.000	0.055	-0.048	-0.099
Inhabitants per km2	-0.145	0.225	-0.370	0.285	0.055	1.000	0.307	-0.242
Highly educated people	-0.143	0.580	0.128	0.588	-0.048	0.307	1.000	0.165
Share of renewable energy	-0.048	-0.033	-0.093	-0.043	-0.099	-0.242	0.165	1.000

Table 6: Pearson Correlation Urban

Rural	Average distance to public transport	Branches	CO2emissions	Unemployment Percentage	LOG_Income	Inhabitants per km2	Highly educated people	Share of renewable energy

Average distance to public transport	1.000	0.183	0.232	-0.109	-0.113	-0.302	-0.232	0.230
Branches	0.183	1.000	0.110	-0.247	0.662	-0.068	-0.029	-0.093
CO2emissions	0.232	0.110	1.000	-0.043	-0.174	-0.311	0.029	0.067
Unemployment Percentage	-0.109	-0.247	-0.043	1.000	-0.298	0.228	0.205	-0.078
LOG_Income	-0.113	0.662	-0.174	-0.298	1.000	0.203	0.096	-0.262
Inhabitants per km2	-0.302	-0.068	-0.311	0.228	0.203	1.000	0.187	-0.358
Highly educated people	-0.232	-0.029	0.029	0.205	0.096	0.187	1.000	-0.038
Share of renewable energy	0.230	-0.093	0.067	-0.078	-0.262	-0.358	-0.038	1.000

Table 7: Pearson Correlation Rural

Key takeaways that become clear from the Pearson correlation matrix in Appendix C, table… is that urban municipalities with higher income levels are positively associated with more businesses (Pearson correlation = 0.500**). Higher-income levels are negatively associated with unemployment rates (Pearson correlation = -0.490**). This means that as income levels rise, unemployment rates tend to decrease in urban municipalities. Higher numbers of highly educated people are associated with more businesses (Pearson correlation = 0.580**), higher unemployment rates (Pearson correlation = 0.588**), and higher population densities (Pearson correlation = 0.307**). A higher population density is associated with lower CO2 emissions (Pearson correlation = -0.370**). Lastly, higher population density is negatively correlated with the share of renewable energy (Pearson correlation = -0.242*), indicating that rural areas might be more invested in renewable energy sources and pro-environmental behavior.

Same as for urban, a negative correlation (-0.298**) with income levels and unemployment rates suggests that higher income levels are associated with lower unemployment rates. Income levels and the number of branches have a strong positive relationship (0.662**), indicating that higher economic activity is associated with higher income levels. Higher population density in rural areas is associated with lower CO2 emissions (-0.311**), possibly due to better public transport and lower reliance on personal vehicles in areas with more inhabitants per km2. Population density is associated with a lower share of renewable energy, just as in urban municipalities (-0.358**), Meaning the more people per km2, the lesser share of renewable energy of the total. It could also be because of higher energy demand in general. There is, however, a positive correlation between distances to public transport and renewable energy usage (0.230**); this can be due to infrastructure and space availability for the generation of renewable energy sources in rural municipalities where there is less public transport.

Similarities

Both urban and rural areas show a negative correlation between CO_2 emissions and population density, indicating that denser areas have lower CO_2 emissions per capita. Economic activity and income levels are positively correlated in both urban and rural areas, with stronger correlations in rural areas. Both urban and rural areas exhibit a significant negative correlation between income levels and unemployment rates. Suggesting an overall increase of income causes a decrease of unemployment rates.

Population density is positively correlated with the number of highly educated people in both urban and rural areas, with a stronger correlation in urban areas. Suggesting that highly educated people tend to live in more urbanized areas.

Differences

Public transport accessibility shows different correlations with the share of renewable energy in urban and rural areas, highlighting different dynamics in these settings. In urban areas, there is no significant correlation between the use of renewable energy and the distance to public transport. However, in rural areas, there is a positive correlation between distance and public transport. This suggests that in rural areas, as the distance to public transport increases and infrastructure worsens, the usage of renewable energy also increases.

The somewhat weak (0.230) positive correlation between infrastructure and renewable energy usage in rural areas suggests that rural municipalities with limited access to public transport may be using more renewable energy sources to reduce overall carbon emissions. This reflects a compensatory behavior, where gaps in public transport infrastructure are being offset by higher adoption of renewable energy.

Appendix D: Multiple Linear Regression Output

Urban

Model	R	R square	Adjusted R square	Sig. F change
1	0.437	0.191	0.105	0.043

Table 8: Model Summary Urban

ANOVA

Model	Sum of Squares	df	Mean Square	F	Significance
1 Regression	222.336	7	31.762	2.220	0.043
Residual	944.305	66	14.308		
Total	1166.641	73			

Table 9: ANOVA Urban

Rural

Model	R	R Square	Adjusted R Square	Sig. F change
1	0.421	0.178	0.145	<0.001

Table 10: Model Summary Rural

ANOVA

Model	Sum Of Squares	df	Mean Square	F	Significance
1 Regression	10.117	7	1.445	5.431	<0.001
Residual	46.836	176	0.266		
Total	56.952	183			

Table 11: ANOVA Rural

Appendix E: Comprehensive Independent Variable Overview and Measurement Methods

Urban versus rural

In CBS statistics for the Netherlands, municipalities are classified as urban or rural based on population density. Municipalities with a high population density, typically more than 1,500 inhabitants per square kilometer, are described as urban, and lower than 1,500 inhabitants per square kilometer are defined as rural. As stated earlier, there are national differences in what is defined as urban and what is defined as rural; this study aligns with what CBS defines as an urban settlement and a rural settlement. The classification is based on address density given by the statistics of CBS (Statistiek, 2023). A grid square of 500 by 500 meters is considered an urban area if the environmental address density of the grid square in question is 1,500 or more addresses per square kilometer.

Structural weaknesses

It is divided into two variables, each accounting for an aspect of the structural weakness of a region. One is infrastructure resilience, and one is economic diversification

1. **Infrastructure resilience**

Infrastructure resilience refers to the capacity of infrastructure networks such as public transportation, energy, and communication to continue functioning effectively in the face of challenges. In this research, it is measured by the average distance to a train station per municipality in the Netherlands. As mentioned in Rodriquez-Pose and Bartalucci's paper, structural weaknesses comprehend factors such as inadequate infrastructure. Using the average distance to a train station per municipality in The Netherlands as an indicator can provide valuable insights into the accessibility and connectivity of regions, reflecting the state of infrastructure in those areas. A low distance to a train station per municipality would indicate better accessibility and connectivity, potentially reflecting stronger infrastructure resilience in the region. Conversely, a high distance to a train station per municipality could suggest lower accessibility and connectivity, indicating potential weaknesses in infrastructure resilience.

2. **Economic diversification**

Refers to the process of expanding a region's economic base by incorporating a variety of industries and sectors. A diversified economy is less reliant on a single industry or sector, reducing its vulnerability to economic downturns or shifts in market demand. This refers to the process of expanding a region's economic base, owning a variety of industries and sectors. A diversified economy is less reliant on a single industry or sector, reducing vulnerability to economic downturns or shifts in market demand (Rodríguez-Pose & Bartalucci, 2023). A diversified economy is less reliant on a single industry or sector, reducing its vulnerability to economic downturns or shifts in market demand. To measure the economic diversion, the share of industries in a municipality in The Netherlands is used as a unit of measurement for the economic diversification.

Emissions

CO_2 emissions refer to the amount of carbon dioxide released into the atmosphere from various sources, including transportation, industry, and energy production (Pachauri et al., 2015). Regions with high CO_2 emissions are considered more vulnerable to the green transition. High emissions indicate a greater reliance on polluting sources of energy and industries, making the region more exposed to the negative impacts of transitioning to a low-carbon economy (Rodríguez-Pose & Bartalucci, 2023). CO_2 emissions are calculated by multiplying the energy carriers (for example, kWh of electricity, m3 of gas, liters of gasoline) by the emission factor of that energy carrier.

Economic decline

Economic decline refers to a reduction in economic activity within a region; economic decline in a vulnerable region is characterized by factors such as low GDP, lower levels of consumer spending, and high unemployment (Rodríguez-Pose & Bartalucci, 2023). Regions experiencing economic decline are more vulnerable to socio-economic challenges, making them less resilient to changes such as the green transition. High unemployment rates indicate economic instability and reduced economic opportunities, which can negatively impact the region's ability to adapt to new economic conditions (Rodríguez-Pose & Bartalucci, 2023). Unemployment rates serve as a reliable indicator of economic health and provide insights into the economic decline of a region.

Control variables

To isolate the effect of vulnerability indicators (independent variables), this study also controls for several factors that have been shown to influence pro-environmental behavior in the literature. These include population density, education level, and income level (Mehmood et al., 2022; Yousaf Raza et al., 2023). Controlling for these variables ensures that the observed effects of the primary independent variables on pro-environmental behavior (PEB) are not confounded by these socio-economic factors. This helps isolate the specific impact of regional vulnerability on renewable energy adoption.

Population density

Population density is included as a control variable because it can significantly impact energy consumption patterns and the feasibility of renewable energy projects. Urban areas with higher population densities often have more infrastructure and policy initiatives promoting renewable energy compared to rural areas (*Rise of Renewables in Cities – Energy Solutions for the Urban Future*, z.d.)

Income

Income level is included as a control variable because higher income levels may enable greater adoption of renewable energy technologies and sustainable practices. Households with higher incomes are more likely to invest in renewable energy systems, such as solar panels and energy-efficient appliances, thus influencing the share of renewable energy in total energy consumption. To address the skewness in the income data and to normalize the distribution, the average household income was log-transformed using the natural logarithm. This transformation helps to meet the assumptions of the regression model and provides a better fit for the data (Smith et al., P., 2020).

Education level

Education level is included as a control variable because higher education levels can enhance environmental awareness and influence pro-environmental behaviors. Highly educated individuals tend to be more informed about environmental issues and are more likely to advocate for and invest in renewable energy solutions, thereby influencing the share of renewable energy in total energy consumption. The number of highly educated people is measured as the absolute number per municipality, providing a direct measure of educational attainment within each area (Dietz et al., R., 2007)

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