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Multilevel Analysis of Civic Engagement and Effectiveness of Energy Transition Policy in Seoul: The Seoul Eco-Mileage Program

Jaewan Kim 1, Tae Yong Jung 1,∗ and Yong Gun Kim 2

1 Graduate School of International Studies, Yonsei University, Seoul 03722, Korea; kjw0422@gmail.com
2 Korea Environment Institute, Sejong 30147, Korea; ygkim@kei.re.kr
∗ Correspondence: tyjung00@gmail.com; Tel.: +82-(0)2-2123-3594

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Abstract: The Seoul Eco-mileage Program is a representative project of the One Less Nuclear Power Plant (OLNPP) scheme, which addresses the energy transition policy of Seoul aiming to reduce CO2 emissions. Unlike other governmental projects, the success of this program requires the direct participation of citizens. This study investigates the influence of civic engagement in participant towns (Level 1: 423 administrative towns) and districts (Level 2: 25 administrative districts) on CO2 emissions reduction (kg CO2/membership) throughout 2017 in Seoul via multilevel modeling. Our results show that town-level civic engagement, as measured by voter turnout, is positively correlated with the performance of the Eco-mileage Program. Moreover, when civic engagement factors (social trust, volunteer activities, and citizen participation) at Level 1 interact with Level 2 factors (housing prices, motivation of district leaders, and energy-saving practices) in each district, we observed cross-level interactive effects on CO2 reduction. Among Level 2 factors, the representative institutional capacities, such as financial independence and ordinance, showed positive correlations with the performance efficacy of the energy transition policy of Seoul.

Keywords: Seoul Eco-mileage program; civic engagement; CO2 reduction; local energy transition; multilevel modeling

1. Introduction

1.1. Background

The cabinet of the Republic of Korea approved the revised “2030 greenhouse gas roadmap” plan on 24 July 2018. A key element of the roadmap involves increasing the share of domestic offset while reducing the scope of international mitigation to meet the 37% reduction target of the nationally determined contribution (NDC) submitted to the UN prior to the Paris Agreement [1,2]. Nevertheless, the Korean government has been criticized for not sufficiently focusing on mitigating domestic and international greenhouse gas (GHG) emissions with specific action plans. The economic structure and energy systems of Korea require substantial changes to avoid enormous costs associated with reducing GHG emissions in the near future [3]. Therefore, diverse efforts from different sectors are required to meet the emissions target for Korea. In particular, the role of local governments and voluntary participation among citizens can significantly contribute to the switch to low-carbon pathways [1,4].

Seoul, a city of 9.7 million people has exerted itself to increase the city’s self-reliance on electricity and strengthen efforts on energy transition by moving from conventional to more sustainable energy paradigm to effectively cope with climate change [5]. Seoul is responsible for consuming a large portion of the energy produced nationwide. For example, the city alone used 10.3% of the country’s
total energy output, which is 46,903 GW h out of total energy output of 455,070 GW h, but only produced 2.95%, which is 1384 GW h of its consumption in 2011 [6]. Moreover, Seoul’s GHG emissions in the residential and commercial sectors comprise 54% of the city’s total emissions (the balance of 46% consisting of transportation, industrial and other sectors) [7]. In that vein, Moran et al. surveyed CO₂ distribution of 13,000 cities worldwide at household level, and Seoul ranked the top in the world [8]. The existing energy-supply system is based on a large-scale centralized method, such that it relies heavily on electricity produced by coal-fired and nuclear power plants (NPPs) located away from the cities. This has led to severe conflicts among local communities regarding the construction of power transmission facilities [9]. Seoul’s efforts to switch from traditional systems to renewable-based self-reliable systems were accelerated with the One Less Nuclear Power Plant (OLNPP) scheme launched in April 2012. This policy aims to reduce 2 million tons of oil equivalent (TOE) electricity, equivalent to the annual production of one NPP. The target was achieved in June 2014, implementing the ongoing second phase of the scheme, with a total reduction of 5.18 million TOE and 11.83 million tons of CO₂ achieved as of December 2018 [10]. According to Lee [11], Seoul’s energy consumption decreased by 4% in 2014 from 2012, whereas the nationwide energy consumption increased by 4.9%. Although energy consumption patterns tend to be influenced by climate or economic variations, the fact that other cities under similar conditions used more energy is indicative of the success of the OLNPP scheme.

The Seoul Eco-mileage Program is a representative project under the OLNPP scheme that has contributed to the reduction of CO₂ emissions in Seoul. The effectiveness of the program turned out to be successful in terms of participation among citizens, the level of energy saved, and CO₂ reduction amount. Especially, in comparison with renewable energy infrastructure, which requires high initial investments, the Eco-mileage Program has been evaluated as a cost effective and efficient way to reduce energy consumption as well as GHG emission. Thus, the program itself is a suitable case to address global demand for energy saving and carbon reduction [12]. Unlike other projects initiated by the authorities, this program requires direct citizen participation. Thus, the efficacy of this policy is likely to be driven by the personal motivation of individuals to participate in civil society. Existing studies on the OLNPP scheme, including the Seoul Eco-mileage Program, have mainly focused on policy evaluation through frameworks, interviews, or participant observation methods. For instance, Lim and Kang [12] adopted a qualitative method—a logic model to assess the outcome of the policy effectiveness, yet they admitted that such an approach fails to investigate the causes of disparity among the participants of the Eco-mileage Program in energy savings. Another study by Yoo et al. [13] conducted in-depth interviews with five participants of the Eco-mileage program to find their motivations of contributing the earned points to the Seoul Energy Fund to help the energy poor population. Although Ko and Song [14]’s study applied a quantitative approach through mathematical models, the focus of the study is building and managing sustainable tourism system rather than evaluating the Eco-mileage performance itself. Consequently, this empirical study is unprecedented by conducting a quantitative analysis to evaluate the efficacy of the Eco-mileage program and to determine the correlation between civic engagement and the effectiveness of the energy transition policy.

1.2. Research Questions and Flow

This research was developed to determine whether civic engagement in each town (Level 1: 423 administrative Dongs) positively impact the Eco-mileage performance, whether district-level (Level 2: 25 administrative Gus) factors influence the effectiveness of the policy, and the intra-class interactive effects between Level 1 and Level 2 variables on the Eco-mileage performance. Therefore, the amount of CO₂ reduction in each Dong through the Eco-mileage Program was investigated by using a multilevel modeling method. In Section 2, we present the conceptual framework, along with a series of hypotheses based on literature reviews of civic engagement as the main vehicle for local energy transitions. Section 3 examines the Eco-mileage Program with the relevant data and methodology. Section 4 presents the results of our hypotheses testing and an examination of the
relevant factors. The final section summarizes our key findings and discusses the policy implications of this study.

2. Theoretical Background

2.1. Literature Review

Energy transition can be defined as moving toward a sustainable energy system, which emphasizes energy efficiency and the use of renewables from fossil fuel and nuclear-based power generation and consumption [15,16]. To successfully achieve local energy transition, a society must mobilize voluntary participation among local level actors, along with new forms of decentralized energy governance and technical and social innovations, such that we can consolidate a strong foundation of social capital [4]. In the new era of energy transition, households, farmers and cooperatives became significant players, therefore civil society such as NGOs and mobilized citizens are added as important key players [17]. In this section, we review literature on new concept of energy transition and its primary elements along with individual level of social capital distinguishable from the traditional feature of aggregate communities.

Lovins [18] suggests the transition from a hard energy path to a soft energy path to improve the energy service and expand the use of renewable energy. A soft energy path enables the implementation of small-scale decentralized energy systems. Lee [16] considers three important aspects of how local (soft) energy systems dovetail with the sustainable energy scheme. First, these systems increase energy self-reliance within the region, thus reducing the environmental load. Second, local energy minimizes negative externalities created during production and consumption. Lastly, local energy generation reduces energy loss and transportation cost, which also vitalizes the local economy. The multilevel perspective (MLP), the technology innovation systems (TIS) approach and niche management are main dominant approaches in transition theory that analyzes the low-carbon energy transition based on the various relationships among technology, social structure, institutions, and cultural perception [17,19,20]. For the establishment of any energy transition policy, especially the MLP encourages interactions among the landscape, regime, and niche. In other words, if the MLP affords validation, the system can be maintained despite landscape-level crises, as the niche-level experiment can transform the existing regime into a more sustainable version [21]. In this context, Seoul’s OLNPP scheme can be viewed as a meaningful niche-level experiment for local energy transition, which can influence state or global energy regimes [9]. Landscape changes, such as the Fukushima accident and climate change threats, reveal the necessity of energy transitions. Moreover, domestic issues, such as regional conflicts over transmission tower construction in Milyang and the blackout experience in Seoul in 2011, have galvanized the citizens of the capital into action for energy self-reliance [22]. Nevertheless, the predominant theories have been criticized for lacking sufficient consideration on the process of transition at the local level, thus Mattes et al.[17] draw ideas on the Regional Innovation Systems (RIS) approach which may be highly beneficial to understand the complexities of the transition process. The study investigates interaction of diverse subsystems including science, politics, public administration, industry, finance, intermediaries and civil society since their interaction represents how energy transitions are formed, not only by institutions, but also by various individual and organizational actors. Among several subsystems, our empirical research framework especially focuses on ‘civil society’, ‘intermediaries’, ‘politics’, and ‘public administration’ to see how the key actors in these areas form social capital which eventually enhances the effectiveness of the Eco-mileage Program. The Seoul Eco-mileage Program puts more weight on citizen’s personal motivation to voluntarily participate in the program, thus a role of civil society as a subsystem becomes more important. Direct participation by diverse stakeholders facilitates bottom-up actions and requires involving intermediaries who can consolidate, grow and diffuse novel innovations within community for the transition [23,24]. In fact, one of the crucial factors that contributes to the success of Seoul’s ONLPP is the role of intermediary organization as another subsystem to support community which consist of voluntary participants. For example, the Seoul Community Support Center (SCSC) as an intermediary organization supports residents to
engage in community building projects such as community cafés, child-care, energy self-reliant villages, and community enterprises [25]. As Mattes et al.[17] divides political subsystem into ‘political agenda’ and ‘daily routine of local government’, we also consider this point separately. For the former, political leadership is included in our analysis in the form of newspaper exposure of district leaders mentioning the Eco-mileage program as an influence on participation [26]. Newspapers are regarded as an essential tool to mobilize voluntary participation among people as they inform people about what others think and this builds a social consensus on desirable direction [27]. Furthermore, one of the successful factors of Seoul’s ONLPP is political leadership of the mayor Park Won-soon who led the formation and implementation of the policy. The former NGO activist mayor Park had regular meetings with heads of local offices and NGOs to communicate with multiple stakeholders during the decision making process [5]. He led the formation and implementation of the policy. For the latter, administrative routine is measured as a subsystem whose interaction shapes energy transition through financial independence and climate change related ordinace of each district.

Putnam [28] discusses the decline of social capital due to weakened civic engagement in the U.S.A. in his famous article titled “Bowling alone.” Putnam [28] begins with the most familiar evidence associated with decreased political participation, i.e., voter turnout in national elections from the 1960s to 1990s. Intrinsic linkage between civic engagement and social capital has been argued by scholars and policy makers since civic engagement may mitigate negative externalities for social capital associated with mistrust and lack of respect [29,30]. Particularly, citizens may become more thoughtful and respectful of each other’s rights through voting in democratic elections [31]. Another study about voter turnout and political participation also finds a positive relationship between people’s beliefs on political authorities and civic engagement [32]. The concept of social capital based on the definition in Putnam [28] can be represented by the features of social organizations, such as networks, norms, and social trusts, where the coordination and cooperation for mutual benefit can be facilitated by such elements of social capital [28]. Moreover, voluntary associations allow people to interact with each other to create social trust and eventually form social capital [28,33]. Putnam [34] also emphasizes that, to achieve collaborative action, individuals must trust that others will not act contrary to shared objectives. Hence, community action toward energy transition is more likely to be implemented according to shared visions or interests among participants [25]. Putnam [34] and Coleman [35]’s classical concept of social capital refers to a feature of aggregate communities such as church groups, labor unions, PTA and fraternal organizations. However, we focus on individual behavior and attitudes which also manifest the phenomenon of social capital in this study. Brehm and Rahn [26] discuss that trust can be built by people who comprise their communities, not by community itself. Therefore, social capital can be viewed as a reciprocal relationship between community involvement and interpersonal trust, as well as individuals’ confidence in government [26]. Two main properties of individual social capital are; first, social relationships like involvement in voluntary association, and second, pro-social norms such as trust [36]. Hence, if we consider our research framework (Figure 1) within these properties, volunteer, participation in social issues, and energy saving activities can be manifested as social relations, whereas voter turnout and level of social trust represent social norms.

2.2. Research Framework

This study develops its argument by emphasizing how civic engagement impacts the effectiveness of the Eco-mileage Program via measuring the amount of CO₂ reduction in relation to other variables from different categories at town and district levels, as Figure 1 represents below. To assess the effectiveness of civic engagement and other factors on the Eco-mileage Program outcomes, we suggest three categories as our analytical framework based on extensive literature review on energy transition and social capital, and we try to incorporate the two domains of theory to develop our main argument. Particularly, the theoretical background of our research questions starts from Lovins’ [18] classic discussions on energy transition and Putnam’s [28,33,34] views on social capital along with several other social capital studies in the field of environmental governance. A society
with higher social capital such as strong social network or reciprocity, tends to cope well with vulnerability to risk from the impact of climate change [37]. In this study, we investigate three categories to comprehend participation among citizens, socio-economic conditions, and institutional settings, that lead a successful urban energy transition. Of these three categories, 11 key factors are considered to investigate the performance of the Eco-mileage Program in 423 towns (Dongs) nested in 25 districts (Gus) in Seoul that participated in this scheme in 2017.

First, civic engagement forms a key factor for local entities to more effectively address climate change. Civic engagement refers to citizen inclusivity in the local government’s decision-making process on climate change [38]. In this case, active citizen involvement forms the successful niche-level experiment that can possibly influence the state or global energy regime [16,39,40]. Studies have long connected voting to the broader concept of civic engagement [41]. A strong argument for adopting voter turnout as a proxy for communities to engage in collective action posits that individuals are more likely to vote if they are involved in political action in general and environmental activism in particular [42,43]. Wollebaek and Selle [44] also adopt the proportion of voting respondents at every parliamentary election as an index of civic engagement. In addition to voter turnout, we consider other forms of civic engagement, such as volunteer work, participation in social issues, and the level of social trust among citizens in each town, to estimate how civic engagement affects the performance of the Eco-mileage Program. Based on this perspective, Coffe and Geys [45] show that, if a civil society is equipped with networks of trust and reciprocity among its citizens, the society tends to show better economic and government performance at the local level. Moreover, practicing energy-saving activities can form a key to the success of the energy transition policy. Based on previous studies, we test the following hypotheses listed in Hypotheses for civic engagement.

Hypothesis 1 (H1). Towns (L1) with higher voter turnout will show higher Eco-mileage performance.

Hypothesis 2 (H2). Towns (L1) with citizens who actively volunteer will yield more CO2 reductions.

Hypothesis 3 (H3). Towns (L1) with more citizen participation in sociopolitical issues will perform better in the Eco-mileage Program.

Hypothesis 4 (H4). Towns (L1) with individuals with a high level of social trust will show better performance of the Eco-mileage Program.

Hypothesis 5 (H5). Districts (L2) with more citizens practicing energy-saving activities, such as using bicycles, saving water, and purchasing used goods, will show better performance in reduction of CO2. 

Figure 1. Conceptual framework of this study.
Second, institutional capacity (Hypotheses for institutional capacity) at the district level contributes differently to the performance of the Eco-mileage Program in each town. Traditionally, administrative and financial capacities have been the significant determinants of the commitment of the local government to federal policy [46]. Similarly, as a part of readiness toward an evolutionary climate resilience policy, Lee and Lee [47] defined resourcefulness as the capacity to mobilize financial, organizational, informational, and institutional resources. Thus, districts with sufficient funding are more likely to adopt innovative experiments and policies [48]. In other words, budget availability, financial stability, and the availability of institutional frameworks, such as ordinances in each district, form key resources for the institutional capacity that enables more effective local government performance [49]. Moreover, effective political leadership is important in building consensus among local communities and different sectors [38]. This can lead to the successful dissemination and adoption of new policies [50]. For example, the success of the Seoul OLNPP can be attributed to firm action (or strong resolve) by the mayor [5].

**Hypothesis 6 (H6).** Districts (L2) with ordinances for low-carbon systems, climate change, or renewable energy will show better performance in the Eco-mileage Program.

**Hypothesis 7 (H7).** Districts (L2) with a higher financial independence ratio will more effectively implement the CO₂ reduction policy.

**Hypothesis 8 (H8).** Districts (L2) with leaders committed to the Eco-mileage Program will perform better at the policy.

Third, the socioeconomic conditions of each town and district influence the performance of the Eco-mileage Program (Hypotheses for socioeconomic conditions). From this perspective, earlier studies have shown that households that belong to relatively higher income brackets are less likely to save energy through daily activities [51,52]. Moreover, data collected by UCLA’s California Center for Sustainable Communities indicates that wealthier neighborhoods use more energy per capita than poorer counterparts in Los Angeles [53]. However, reducing energy use is difficult to implement up to certain levels of income groups as there is insufficient room for reductions from current consumption levels. Thus, in this study, we used the square of the income variable to test this assumption. In terms of demographics, previous studies have empirically proven that when the population of the municipality doubles, energy efficiency can increase by 12% [54]. Hence, we assume that areas with higher population, or larger numbers of households in this study, correspond to increased CO₂ reductions.

**Hypothesis 9 (H9).** Districts (L2) with higher housing prices will have less of an impact on CO₂ emissions reduction.

**Hypothesis 10 (H10).** The CO₂ emissions reduction in each town (L1) will increase up to a certain level with respect to the squared income, with a subsequent decrease.

**Hypothesis 11 (H11).** Towns (L1) with larger numbers of households will show higher performance in the Eco-mileage Program.

3. Case and Data

3.1. Seoul Eco-Mileage Program

The Seoul Eco-mileage Program was launched in September 2009 to reduce GHG emissions via energy-efficient and energy-saving activities. Although the Eco-Mileage Program existed prior to the formulation of the OLNPP, this program is a key element of the Seoul OLNPP scheme [55]. As per the GHG inventory of the Seoul city government, 71% of the total emissions are due to households and buildings, followed by the transportation sector at 22%. Therefore, it is rational to encourage households and businesses to participate in voluntary energy conservation measures, such as the Eco-mileage Program. The program targets four areas, i.e., electricity, water, gas, and heating, to
measure the amount of energy saved and calculate the amount of CO₂ reductions. The amount of energy saved from participation in the program is estimated as points. For example, if a household reduces 10% of its GHG emissions relative to the same period based on the previous 2-year average, that household can earn 50,000 mileage points (equivalent to KRW 50,000). The earned mileage can be used to purchase ecofriendly goods, pay for public transportation, apartment management fees, and local taxes, among other options [55–57].

As previously discussed, the main policy objective of Seoul’s OLNPP is to achieve the city’s energy self-reliance. Renewable energy generation, increasing energy efficiency, and energy savings form the main components of the energy self-reliance ratio (Equation (1)) [22]. As the Eco-mileage Program focuses on energy savings through demand management in each Dong, it can contribute to the city’s medium-long-term policy agenda, i.e., accomplishing Seoul’s energy self-reliance and reducing GHG emissions as follows:

\[
\text{Energy self-reliance ratio} (\%) = \frac{\text{Production + Reduction}}{\text{Consumption}} \times 100
\]  

(1)

3.2. Data Collection and Variables

Table 1 lists the data used in this study and their sources. As a dependent variable, in 2017, the amount of CO₂ reductions (kg CO₂/membership) in each participating town was compared with the data for the same period from two previous years. Individual member data were aggregated by each town and divided by the number of membership accounts to estimate the average value of CO₂ reductions in each town. Only households and small business members were considered among other Eco-mileage participants, as their contributions to the program were the largest among other groups. Moreover, their engagement in the program is more strongly driven by personal motivation regarding this social issue than that of other group members, such as schools, churches, and firms. Relevant data were collected from the Seoul Metropolitan Government (SMG) open data portal [58].

Table 1. Variables and data sources.

| Category                  | Variable                                                                 | Source                                |
|---------------------------|--------------------------------------------------------------------------|---------------------------------------|
| Performance (DV)          | Reductions in CO₂ emissions amount per membership (kg CO₂/membership) in 2017 in each participating town (Dong) in Seoul | Seoul Metropolitan Government (SMG) open data |
|                           | Voter turnout for the 20th Assembly Election in each town                  | National Election Commission          |
|                           | Level of volunteer activities among citizens in each town                  | '17 Seoul Survey                      |
|                           | Level of citizen participation in social issues in each town               | '17 Seoul Survey                      |
| Civic engagement          |                                                                 | '17 Seoul Survey                      |
| [Levels I, II]            | Level of social trust among citizens in each town                         | Seoul Metropolitan Government (SMG) open data |
|                           | Citizen practices concerning energy-saving activities in each district    | Naver portal news                    |
| Institutional capacity    | Existence of district ordinances on low-carbon systems, climate change, or renewable energy (yes: 1, no: 0) | Seoul legal admin. service            |
| [Level II]                | Financial independence ratio of each district (%)                         | Seoul Metropolitan Government (SMG) open data |
|                           | Resolve of district chief about the program as reported in newspapers in 2017 | Naver portal news                    |
| Socioeconomic conditions  | Housing transaction price index in each district                          | SMG Open Data                         |
| [Levels I, II]            | Income level of each household in town                                    | '17 Seoul Survey                      |
|                           | No. of households in each town                                            | '15 Population and housing census    |
Data representing independent variables were collected and processed as follows. First, for civic engagement, voter turnout, which represents the percentage of voting participants in the 20th Assembly Election (2016), was acquired for each town from the National Election Commission webpage [59]. The components of social capital, such as citizen volunteer activities, level of citizen participation in social issues, and social trust level among citizens in each town, derive from the results of the 2017 Seoul Survey [60]. Volunteer activities represented the number of activities in which each citizen was involved during 2016. The level of participation in social issues was calculated by asking citizens whether they had participated in seven suggested social issues; citizens could reply with 0 if their answer is ‘no’ or 1 if it is ‘yes’ for each item. The gathered information was summed for each survey respondent. The level of trust was measured based on the Likert scale, with 1 corresponding to no trust and 4 representing the highest trust. All values of each variable, i.e., volunteer, participation, and trust, were aggregated for each town and divided by the number of respondents to obtain the average value. Finally, data regarding citizen practices in energy-saving activities at each district level were collected from the SMG Open Data Portal [58] based on survey results. Respondents selected scores from 1 (do not practice) to 5 (always practice) for four specific energy-saving activities. These values were converted to the average value calculated on a 10-point basis.

For institutional capacity, the financial independence ratio for each district was collected from the SMG Open Data Portal [58]. The existence of district ordinances relevant to low-carbon systems, climate change, or renewable energy were determined from the Seoul legal administration service portal [61]. If a district had an ordinance from a certain year onward, a score of 1 was assigned; otherwise, the score was 0. Pro-environmental leadership has been practiced by administrative leaders in various levels of governmental bodies [62]. Among innumerable theories of administrative leadership, Portugal and Yukl’s conceptualization of effective environmental leadership is to advocate environmental goals and strategies, and communicate the needs, values, and benefit of environmental protection [63,64]. In this context, considering the resolve/motivation of the district chief regarding the Eco-mileage Program through news articles can be viewed as a reasonable approach to show effective pro-environmental leadership. Because the leadership was difficult to quantify, this variable was measured based on the number of news articles related to the search terms “Eco-mileage” and “district chief” at the Naver website (a Korean web search engine) [65]. The number of articles with content focusing on district chiefs and the program in 2017 was counted and summed for each district. As newspaper exposure is influential on mobilizing citizen participation by informing them about what others think, newspapers can be regarded as an important catalyst to form voluntary association [26,27]. A study also finds that local newspapers constitute a shared public sphere where people can collect information and share the awareness of local events, politics, and volunteering [66]. Another study by Shah et al. investigates a positive correlation between informational uses of various media such as the Internet, TV, and newspapers and individuals’ production of social capital [67].

For the socioeconomic conditions, we used the SMG open data source to estimate the average housing transaction price index per district [58]. This index indicates the transaction price ratio in November 2017 with respect to the base year price in June 2015, which was considered as 100. Household-income-level data were collected as per the 2017 Seoul survey, which offered 19 different income categories for each individual to select [60]. The average values for each town were calculated for the analysis while the squared term was used to test the income effect, where energy reductions can increase up to a certain income level and subsequently decrease. For the number of households in each town, the latest population and housing census numbers from Statistics Korea (2015) were used [68]. The natural log function was applied for standardization. Table 2 lists the descriptive statistics for the dataset.
Table 2. Descriptive statistics for the data used in this study.

| Variable                          | OBS | Mean  | S.D.  | Min  | Max   |
|-----------------------------------|-----|-------|-------|------|-------|
| DV                                |     |       |       |      |       |
| \( CO_2 \) reduction              | 423 | 8.27  | 54.33 | -543.08 | 479.68 |
| Voter turnout                     | 423 | 57.94 | 5.05  | 39.73 | 69.77 |
| Volunteer work                    | 423 | 12.82 | 8.73  | 0     | 54.17 |
| Participation                     | 423 | 1.86  | 1.17  | 0     | 6.37  |
| Trust                             | 423 | 2.39  | 0.51  | 1.00  | 3.73  |
| Income squared                    | 423 | 87.9  | 36.21 | 9.66  | 249.94 |
| Income                            | 423 | 9.19  | 1.88  | 3.11  | 15.81 |
| Log No. of households             | 423 | 9.00  | 0.51  | 5.37  | 9.97  |
| Level 1                           |     |       |       |      |       |
| (423 towns)                       |     |       |       |      |       |
| Ordinance                         | 25  | 0.84  | 0.37  | 0     | 1     |
| Financial Independence            | 25  | 31.74 | 12.66 | 17.80 | 58.40 |
| Housing price index               | 25  | 100.55| 0.45  | 100.12| 101.50|
| Energy-saving activities          | 25  | 19.58 | 0.58  | 18.40 | 20.61 |
| Leadership                        | 25  | 12.00 | 10.41 | 0     | 36.00 |

4. Analysis and Discussion

We applied a multilevel analysis to obtain results from nested data structures that 423 administrative Dongs belong to 25 Gus in Seoul. Nested data structures have a problem of violating the independence assumption of traditional statistics in ANOVA and ordinary least-squares (OLS) multiple regression. For instance, math scores of students in the same school tend to exhibit higher correlation than the scores of students from different schools as they share the same environment for academic performance. Adopting multilevel modeling in a real-life setting enables us to avoid Type I errors and biased parameter estimates [69]. As the data in this study correspond to reduction amount of the \( CO_2 \) emission in each Dong nested in the higher level of districts in Seoul, the use of multilevel regression analysis is plausible, as illustrated in Figure 2 [70]. We used the hierarchical linear model (HLM 8.00) for statistical analysis.

4.1. Random Coefficient Multilevel Model: Estimating the Base Model

This study aims to estimate which factors influence the amount of \( CO_2 \) reduction, i.e., the effectiveness of the Eco-mileage Program in each town in Seoul through base and research models.
Therefore, the base model, represented by Equations (2)–(4), allows researchers to estimate the variability of dependent variables at each level and the reliability of the group mean value for each district [70].

[Level 1 Model (423-town level)]

\[ \text{REDUCED } CO_{2ij} = \beta_{ij} + r_{ij}, r_{ij} \sim N(0, \sigma^2) \]  

(2)

[Level 2 Model (25-district level)]

\[ \beta_{ij} = \gamma_{00} + u_{0j}, u_{0j} \sim N(0, \tau_0) \]  

(3)

[Mixed Model]

\[ \text{REDUCED } CO_{2ij} = \gamma_{00} + u_{0j} + r_{ij} \]  

(4)

Based on the analysis results listed in Table 3, we note that the Level 2 random effect \((u_{0j})\) is statistically significant \((p < 0.1)\). This indicates that both town and district level factors affect the program performance. Before analyzing any nested dataset, we must confirm whether multilevel modeling is required. If no variation is observed in the dependent variable across Level 2 units, the ordinary least squares (OLS) multiple regression is more appropriate [69]. To estimate the extent that the CO\(_2\) reduction is influenced by the Level 2 random effect in each town, we calculated the intra-class correlation (ICC) [71]:

\[ ICC = \frac{\tau_{00}}{\tau_{00} + \sigma^2} = \frac{60.20}{60.20 + 2895.44} = 0.02 \]  

(5)

Therefore, 2% of the total variance can be explained by Level 2 factors and the remaining 98% relies on Level 1 factors.

| Table 3. Multilevel regression results for estimating the base model. |
|-------------------------------------------------|
| Fixed Effect | Coefficient | Standard Error | T-Ratio | p-Value |
| For INTERCEPT1, \( \beta_0 \) | | | | |
| INTERCEPT2, \( \gamma_{00} \) | 8.26 ** | 2.99 | 2.76 | 0.011 |
| Random Effect | Standard Deviation | Variance Component | \( \chi^2 \) | |
| INTERCEPT, \( u_{0j} \) | 7.76 | 60.20 | 33.69 * | 0.09 |
| Var (Residual), \( r_{ij} \) | 53.81 | 2895.44 | | |

Standard errors in parentheses, **: \( p < 0.05 \), *: \( p < 0.1 \)

4.2. Random Coefficient Multilevel Model: Estimating the Study Model

Our study model further develops the base model to estimate how Level 1 and Level 2 factors affect CO\(_2\) reductions by considering Level 2 random effects [70]:

[Level 1]

\[ \text{REDUCED } CO_{2ij} = \beta_{ij} + \beta_{1j} \times \text{(VOTER TURNOUT}_{ij}) + \beta_{2j} \times \text{(VOLUNTEER}_{ij}) + \beta_{3j} \times \text{(PARTICIPATION}_{ij}) + \beta_{4j} \times \text{(TRUST}_{ij}) + \beta_{5j} \times \text{(INCOME}_{ij}) + \beta_{6j} \times \text{(INCOME}_{ij}) + \beta_{7j} \times \text{(LN No. of HH}_{ij}) + r_{ij}, r_{ij} \sim N(0, \sigma^2) \]  

(6)

[Level 2]

\[ \beta_{ij} = \gamma_{00} + \gamma_{10} \times \text{(ORDINANCE}_{ij}) + \gamma_{02} \times \text{(FINANCIAL INDEPENDENCE}_{ij}) + \gamma_{03} \times \text{(HOUSING PRICE}_{ij}) + \gamma_{04} \times \text{(ENERGY SAVING}_{ij}) + u_{0j}, u_{0j} \sim N(0, \tau_0) \]  

\[ \beta_{1j} = \gamma_{10} + \gamma_{11} \times \text{(HOUSING PRICE}_{ij}) \]  

\[ \beta_{2j} = \gamma_{20} + \gamma_{21} \times \text{(ENERGY SAVING}_{ij}) \]
program performance is stronger in districts with relatively low housing prices. As we planned to
deteriorates in districts with higher housing prices. In contra

HOUSING PRICE

On average, the effect of energy saving activities reduce 7.06 kg CO\(_2\) per Eco
mileage membership at the 10% significance level. Districts with one more unit
of each district, with other factors fixed, leads to a reduction of 24.46 kg CO\(_2\) per

Moreover, increased district

in citizen participation (voting) in each town led to an average reduction of 0.898 kg

of squared income is unchanged. For income, the results are expected, but hold no stati

The analysis results listed in Table 4 indicate that Level 1 factors, namely VOTER TURNOUT in
the 20th National Assembly election (2016) [59] and the LN NO of HH that indicate logged number
of household in each town, are statistically significant at 1% significance level. Hence, a 1% increase
in citizen participation (voting) in each town led to an average reduction of 1.19 kg CO\(_2\) per Eco-mileage membership in each town at the 1% significance level, with all other variables fixed. Moreover, a 10% increase in the number of households tended to reduce the average by 0.86 kg CO\(_2\) per Eco-mileage membership at the 1% significance level in each town when other factors remained unchanged. For income, the results are expected, but hold no statistical significance. The coefficient of squared income is −0.04, which indicates that the effectiveness of the program tends to increase up to a certain income level and decreases thereafter. This suggests that, if the disposable income is too low, further reduction in energy consumption is difficult, whereas higher income groups have less motivation for energy savings.

The Level 2 factors of ORDINANCE regarding low-carbon systems, climate change, or
renewable energy, FINANCIAL INDEPENDENCE of each district, average HOUSING PRICE, and
ENERGY SAVING activities in each district are statistically significant. Therefore, the average effect of having a relevant ordinance in each district, with other factors fixed, leads to a reduction of 24.46 kg CO\(_2\) per membership at the 5% significance level. Furthermore, every district with a 1% higher FINANCIAL INDEPENDENCE than the average level corresponds to a reduction of, on average, 0.86 kg CO\(_2\) per Eco-mileage membership at the 10% significance level. This indicates that the Level 2 institutional capacity is significant for a successful energy transition. The average HOUSING PRICE per district has a negative correlation with CO\(_2\) reductions. A 1% higher housing price results in a CO\(_2\) reductions decrease by 19.07 kg CO\(_2\) per membership at the 5% significance level relative to the district-level average housing price. Moreover, increased district-level ENERGY SAVING activities positively affect the program performance at the 10% significance level. Districts with one more unit of energy-saving activities reduce 7.06 kg CO\(_2\) more per membership than the district average.

In addition to the Level 1 and 2 effects, cross-level interaction effects also reduce CO\(_2\) emissions. On average, the effect of VOTER TURNOUT is highly significant after its adjustment with the HOUSING PRICE. The positive correlation between Level 1 voter turnout and CO\(_2\) reductions deteriorates in districts with higher housing prices. In contrast, the effect of voting behavior on program performance is stronger in districts with relatively low housing prices. As we planned to

\[ \beta_{3j} = \gamma_{30} + \gamma_{31} \times (HOUSING \ PRICE_j) \]
\[ \beta_{4j} = \gamma_{40} + \gamma_{41} \times (LEADERSHIP_j) \]
\[ \beta_{5j} = \gamma_{50} \]
\[ \beta_{6j} = \gamma_{60} \]
\[ \beta_{7j} = \gamma_{70} \]

[Mixed Model]

\[
\text{REDUCED CO}_{2iij} = \gamma_{00} + \gamma_{01} \times (ORDINANCE_i) \\
+ \gamma_{02} \times (FINANCIAL \ INDEPENDENCE_i) \\
+ \gamma_{03} \times (HOUSING \ PRICE_i) + \gamma_{04} \times (ENERGY \ SAVING_i) \\
+ \gamma_{10} \times (VOTER \ TURNOUT_{ij}) \\
+ \gamma_{11} \times \text{(HOUSING PRICE}_j) \times \text{(VOTER TURNOUT}_{ij}) \\
+ \gamma_{20} \times (VOLUNTEER_{ij}) \\
+ \gamma_{21} \times (ENERGY \ SAVING_i) \times \text{(VOLUNTEER}_{ij}) \\
+ \gamma_{30} \times (PARTICIPATION_{ij}) \\
+ \gamma_{31} \times \text{(HOUSING PRICE}_j) \times (PARTICIPATION_{ij}) \\
+ \gamma_{40} \times (TRUST_{ij}) + \gamma_{41} \times (LEADERSHIP_j) \times \text{(TRUST}_{ij}) \\
+ \gamma_{50} \times \text{(INCOME}_{ij}^2) + \gamma_{51} \times \text{(INCOME}_{ij}) \\
+ \gamma_{70} \times \text{(LN No. of HH}_{ij}) + u_{ij} + r_{ij}
\]
estimate the effectiveness of civic engagement at Level 1 on the performance of the energy transition policy, we considered several relevant variables indicative of such characteristics, such as VOLUNTEER, PARTICIPATION, and TRUST, which were included as Level 1 factors and whose coefficients represented positive correlations. However, none of these characteristics were statistically significant by themselves. Thus, there was no sufficient evidence to reject the null hypothesis. Nevertheless, when these interact with Level 2 variables, such as ENERGY SAVING, HOUSING PRICE, and LEADERSHIP, we observed statistical significance. For example, citizen involvement in VOLUNTEER work by itself has no effect on CO$_2$ reductions. However, when we consider the Level 2 variable ENERGY SAVING, the Level 1 variable VOLUNTEER positively affects CO$_2$ reductions. Likewise, citizen PARTICIPATION in social issues at Level 1 does not reject the null hypothesis; however, districts with higher HOUSING PRICE at Level 2 render this correlation effective by lessening the effect of citizen participation on CO$_2$ reductions by 2.81 kg CO$_2$ at the 10% significant level. Lastly, the effect that social TRUST among citizens has on the Eco-mileage performance, which is not statistically significant by itself, becomes significant when it interacts with the Level 2 variable of LEADERSHIP. This proves that town-level civic engagement through volunteer work, social participation, and trust can be more meaningful and substantial when district-level institutional support is available.

| Fixed Effect | Coefficient | Standard Error | T-Ratio | p-Value |
|--------------|-------------|----------------|---------|---------|
| For INTERCEPT1, $\beta_0$ |             |                |         |         |
| INTERCEPT2, $\gamma_{y0}$ | 8.58 *** | 2.42 | 3.55 | 0.002 |
| ORDINANCE, $\gamma_{y1}$ | 24.46 ** | 10.07 | 2.43 | 0.025 |
| FINANCIAL INDEPENDENCE, $\gamma_{y2}$ | 0.86 * | 0.44 | 1.96 | 0.064 |
| HOUSING PRICE, $\gamma_{y3}$ | -19.07 *** | 8.04 | -2.37 | 0.028 |
| ENERGY SAVING, $\gamma_{y4}$ | 7.06 * | 3.91 | 1.81 | 0.086 |
| For VOTER TURNOUT slope, $\beta_1$ |             |                |         |         |
| INTERCEPT2, $\gamma_{y10}$ | 1.19 *** | 0.45 | 2.66 | 0.008 |
| HOUSING PRICE, $\gamma_{y11}$ | -1.55 ** | 0.68 | -2.27 | 0.024 |
| For VOLUNTEER slope, $\beta_2$ |             |                |         |         |
| INTERCEPT2, $\gamma_{y20}$ | 0.33 | 0.29 | 1.15 | 0.250 |
| ENERGY SAVING, $\gamma_{y21}$ | 1.28 *** | 0.43 | 3.02 | 0.003 |
| For PARTICIPATION slope, $\beta_3$ |             |                |         |         |
| INTERCEPT2, $\gamma_{y30}$ | 0.82 | 2.48 | 0.33 | 0.741 |
| HOUSING PRICE, $\gamma_{y31}$ | -2.81 * | 1.50 | -1.87 | 0.062 |
| For TRUST slope, $\beta_4$ |             |                |         |         |
| INTERCEPT2, $\gamma_{y40}$ | 0.32 | 7.74 | 0.041 | 0.967 |
| LEADERSHIP, $\gamma_{y41}$ | 0.79 ** | 0.39 | 2.05 | 0.041 |
| For INCOME$^2$ slope, $\beta_5$ |             |                |         |         |
| INTERCEPT2, $\gamma_{y50}$ | -0.04 | 0.40 | -0.10 | 0.918 |
| For INCOME slope, $\beta_6$ |             |                |         |         |
| INTERCEPT2, $\gamma_{y60}$ | 1.88 | 7.30 | 0.26 | 0.797 |
| For LN_NO of HH slope, $\beta_7$ |             |                |         |         |
| INTERCEPT2, $\gamma_{y70}$ | 8.98 *** | 2.88 | 3.12 | 0.002 |

| Random Effect | Standard Deviation | Variance Component | $\chi^2$ | p-Value |
|---------------|--------------------|-------------------|---------|---------|
| INTERCEPT, $u_{0j}$ | 5.06 | 25.59 | 22.62 | 0.307 |
| Var (Residual), $\tau_{ij}$ | 52.88 | 2796.23 |

Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

From Table 5, we note that the total variances in the base and study models are different. As the total variance of the base model (61.57) is larger than that of the study model (57.94), the study model (which includes more Level 1 and Level 2 independent variables) better explains the performance of the Eco-mileage Program [70,72].
Table 5. Total variance in the base and study models.

|                    | Level 1 Variance | Level 2 Variance | Total Variance |
|--------------------|-----------------|-----------------|----------------|
| BASE MODEL         | 53.81           | 7.76            | 61.57          |
| STUDY MODEL        | 52.88           | 5.06            | 57.94          |

4.3. Discussion

The overall results of the multilevel analysis answer the research questions posed in this study via hypotheses testing, as summarized in Table 6. First, civic engagement in each town positively correlates with the Eco-mileage performance. Higher voter turnout rates in each town yield increased CO₂ reductions, corresponding to improved Eco-mileage performance. Our results show that voter turnout can be used as a proxy to measure civic engagement [42]. However, other Level 1 factors in the civic engagement category, such as volunteering, participation, and trust, do not support our hypotheses. Such variables only partially influence program efficacy upon interaction with Level 2 variables. This study does not find statistical significance on income factor as in Table 6 (H10).

Second, district-level factors influence the effectiveness of the Eco-mileage policy. This proves that the institutional capacity of local governments is helpful for successful policy implementation. For instance, districts with ordinances on low-carbon systems, climate change, or renewable energy more effectively reduce energy consumption. The purpose of proposing such ordinances is to induce the participation of local entities to mitigate and adapt to climate change. Therefore, districts with relevant ordinances may better perceive the necessity of GHG reductions [46]. Moreover, districts with higher financial independence are more likely to reduce CO₂ emissions. Although the success of the Eco-mileage Program is subject to voluntary participation among citizens, institutional capacity, particularly financial capacity, significantly determines the performance level. Similarly, strong leadership associated with the implementation of energy transition policies is important to adopt new policies, although this factor is partially supported through the interaction term used in this study [50].

Finally, intra-class interactive effects between Level 1 and Level 2 variables also affect the Eco-mileage performance. From Figure 3a, we note that the effect that voter turnout has on the Eco-mileage Program reduces as the housing price increases. A similar pattern is observed when citizen participation interacts with the housing price factor Figure 3b. This means that the correlation between civic engagement and policy effectiveness in each town is dependent on the socioeconomic condition of the average district housing price. As discussed in the previous section, affluent neighborhoods tend to show less motivation in reducing daily energy consumption. Furthermore, citizens' volunteer activities can contribute more to CO₂ reduction where higher level of energy saving practices are implemented as Figure 3c illustrate.

Table 6. Test results of hypotheses.

| Category                  | Hypothesis                                                                 | Result                      |
|---------------------------|-----------------------------------------------------------------------------|-----------------------------|
| Civic engagement          | (H1) Towns with higher voter turnout will show higher performance in the Eco-mileage Program. | Support                     |
| [Levels I, II]            | (H2) Towns with citizens who do volunteer work more actively will decrease CO₂ emissions. | Only support with intra-class effect |
|                           | (H3) Towns with increased citizen participation in sociopolitical issues will perform better in the Eco-mileage Program. | Only support with intra-class effect |
|                           | (H4) Towns with individuals whose level of social trust is high will show better performance in CO₂ reduction. | Only support with intra-class effect |
|                           | (H5) Districts with more citizens who practice energy-saving activities, such as using bicycles, saving water, and purchasing used goods, will show better performance in the Eco-mileage Program. | Support                     |
### Institutional capacity [Level II]

| Hypothesis | Description | Support |
|------------|-------------|---------|
| (H6)       | Districts with ordinances on low-carbon systems, climate change, or renewable energy will show better performance in the Eco-mileage. | Support |
| (H7)       | Districts with a higher financial independence ratio will implement the policy better. | Support |
| (H8)       | Districts with leaders committed to the Eco-mileage Program will perform better. | Only support with intra-class effect |

### Socioeconomic conditions [Level I, II]

| Hypothesis | Description | Support |
|------------|-------------|---------|
| (H9)       | Districts with higher housing prices will have less of an influence on CO\(_2\) reductions. | Support |
| (H10)      | CO\(_2\) reductions in each town will increase up to a certain level of (squared) income, with a subsequent decrease. | Not Supported * |
| (H11)      | Towns with a larger number of households will show a higher performance in the Eco-mileage. | Support |

* “Not Supported” indicates that this study could not find a statistically significant result.

Lastly, highly motivated district leaders can affect social trust toward CO\(_2\) reduction [Figure 3d]. Therefore, institutional support, as well as socioeconomic conditions at the district level, can critically enhance the contribution of civic engagement to the success of the Eco-mileage Program.

![Graph (a): Housing Price Impact on Voter Turnout](image1)

![Graph (b): Housing Price Impact on Participation in Social Issues](image2)
Figure 3. Intra-class interactive effects. (a) Voter turnout(L1) x Housing price (L2); (b) Participation(L1) x Housing price(L2); (c) Volunteer(L1) x Energy saving practices(L2); (d) Social trust (L1) x Leadership (L2).

5. Conclusions

This study investigated the effectiveness of the Eco-mileage Program in terms of civic engagement in 423 towns nested in 25 districts of Seoul by using a multilevel analysis. The policy implications of the analysis are as follows. First, civic engagement is essential to enhance the effectiveness of the energy transition policy. Increasingly systemized and concrete social conditions can induce the needed citizen engagement. Second, the concept of social capital, which can be consolidated through trust among members of society, participation in social issues, and voluntary contributions, should be included in the policy arena. In general, governmental policies do not consider civil society. However, as society progresses to more advanced stages, the role of citizens becomes more significant. Third, any institutional support from the local government is important for the purpose of effective civic engagement toward energy transition. When institutional support collaborates with civic engagement, policy performance tends to be amplified. Therefore, steady efforts in this direction by local governments are required.

This study tested whether the concept of individual social capital is applicable to climate change, and it analyzed the effect of civic engagement on the performance of local energy transition policies through the case of the Seoul Eco-mileage Program. First, the study combines the concepts of social capital, civic engagement, and local energy transition. Second, micro data from the 423 towns were
subjected to a multilevel analysis. Very few quantitative studies have been conducted on the specific topic of the Eco-mileage Program, and this empirical exercise can provide a more objective and analytical framework to understand the possible outcomes. Finally, the research discusses policy implications for local entities by emphasizing the significant role of local governments in providing institutional support along with creating friendly conditions to induce active civic engagement. Our findings establish a solid foundation for the implementation of local energy transition policies in terms of effectively responding to current climate change issues.

Despite the usefulness of the results, the present research has some limitations. First, due to the data constraints in the multilevel analysis, only the cross-sectional approach can be considered to test the hypotheses. The Seoul metropolitan government only provides town-level detailed information on the Eco-mileage Program for a certain period of time. Thus, the analysis is only cross-sectional. When more detailed data are available for further policy analysis, more accurate and rigorous research methods considering the time-series aspect can be implemented. Second, the variables of civic engagement measurement such as voter turnout, level of trust among citizens, participation in social issues, and volunteer activities may not be completely suitable proxy variables. Although theoretical explanations have been presented, it could be argued that the complex concepts of social capital and civic engagement were oversimplified. Last, the socio-economic conditions considered in this study can be adjusted to be more moderate to match the contexts of the new era of energy transition. For example, the numbers of professional and interdisciplinary energy NGOs could not be included in the quantitative analysis since the serving area of such entities covers Seoul as a whole or even a larger region. Furthermore, the city of Seoul has not held an energy referendum which is another important element in discussing a theory of energy transition. Instead, this study takes into account the existence of relevant ordinances for low-carbon, climate change and renewable energy at the district level. Moreover, administrative discretion which refers to the flexible execution of judgment and decision making that public administrators consider, such as eco-helping and eco-civic engagement behavior in the public sector could have been contemplated as another significant factor that promotes environmental sustainability [73,74]. Nevertheless, our research renders meaningful contribution to find correlations between civic engagement and effectiveness of energy transition. The results can be used for further policy implications and serve as the basis for further research on this topic by developing more sophisticated measurements to gauge the nebulous and unquantifiable aspects of the study.

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