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The Geographical Distribution and Correlates of Pro-Environmental Attitudes and Behaviors in an Urban Region

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Abstract: A lot of emphasis has been put on the densification of urban form to reduce greenhouse gas emissions from transportation. However, many recent studies have found that central urban dwellers, even though their carbon footprints of daily transportation may be lower, might be responsible for higher total emissions than those that reside in suburban areas. Similarly, as with the urban form, higher environmental concern is often considered as an indicator of lower emissions, but several studies have found that pro-environmental attitude (PEA) does not always correlate with less energy intensive behavior. This study analyzes how urban zones, PEA, and several sociodemographic variables are associated with annual travel emissions and pro-environmental behaviors (PEB), using a dataset collected with a map-based online survey (softGIS) survey, contributed by 841 participants from the Helsinki Metropolitan Area (HMA), Finland. Although PEA can affect PEBs related to household energy consumption (β = 0.282, $p < 0.001$), clothing (β = 0.447, $p < 0.001$) and produce purchases (β = 0.449, $p < 0.0001$), their relationship with emissions from local (β = −0.067), national (β = −0.019) and international (β = −0.016) travel was not significant. Clusters of low emissions from local travel and high international travel emissions were found in pedestrian-oriented urban zones and residents of car-oriented zones were more likely to conserve household energy (β = 0.102, $p < 0.05$). These results might help broaden the current perspective of city planners, as well as identify opportunities for more effective mitigation policies.

Keywords: pro-environmental attitude; pro-environmental behavior; greenhouse gases; urban zones; local travel; national travel; international travel

1. Introduction

Anthropogenic activity contributes to global warming, changes in the water cycle, changes in climate extremes, rising of sea levels, and the melting of ice caps. In fact, it is extremely likely that humans have been the dominant cause since the 1950s by contributing to an increased concentration of greenhouse gas (GHG) emissions in the atmosphere, which is the main cause of climate forcing [1]. The current state of anthropogenic activity is distressing the earth system, in some cases, beyond the planetary boundaries [2].

The production and consumption activities of cities are responsible for the majority of global GHG emissions [3]. While around half of the world's population resides in urban areas, cities have been said to be responsible for 71% to 76% of global energy-related CO_2 emissions [4]. The mitigation of these GHG emissions has been a common focus of researchers and policy-makers.

As cities become more compact, distances between services decrease, resulting in less dependency on cars and shorter trip lengths [5–12]. Many cities have emphasized dense urbanization and the reduction of emissions from the private transport sector in their plans, even though these aspects may constitute only a small part of cities' total baseline emissions [13] and factors other than land use planning may have a more decisive role in shaping the structure of emissions from travel [14].

Emissions from aviation are rarely included in city-level policies and studies, even though they can exceed those from ground transport in wealthy European countries [15–17], especially when short-lived climate forcers are included in calculations. The aviation sector currently produces 2% to 3% of total anthropogenic carbon emissions [18,19] and the emissions from it are expected to grow at a rate of around 8% annually [20]. Emissions related to tourism alone account for 8% of global GHG emissions [21].

Many recent studies have found that urban dwellers, although their carbon footprints of local transportation may be lower, are responsible for higher emissions than those that reside in rural areas, due to higher consumption levels [22–28]. Several studies have also extended this pattern to within city-levels, reporting higher carbon footprints in the densest city centers in comparison to those in the outer urban areas [29–33]. This pattern is also related to the so-called rebound effect; cars are expensive to possess and operate, and a car-free lifestyle provides new consumption opportunities that seem to be taken advantage of, resulting in the overall emission load being higher than when possessing and operating a car [34].

Another popular urban planning and development related mitigation strategy is the creation of more energy efficient housing as 68% of cities plan GHG reductions in the building sector [13]. However, while housing energy related emissions might indeed go down significantly along with new energy efficient buildings, again, the overall carbon footprints of the residents might still show upward curves due to higher consumption levels [30].

One of the most common policy levers for GHG mitigation is the raising of awareness [13,35]. However, although public awareness of the impacts of global warming is growing, studies on reduced emissions or changes in behaviors of concerned citizens vary. This implies that there are awareness–attitude–behavior gaps, where an individual's awareness, values, or beliefs are not reflected in their actions or market behaviors. Some suggest that comfort, convenience, and cost overrule values, and barriers include the lack of relevant information easily available, organizational challenges, and time and money constraints [36], and that pro-environmental self-identity may not translate to pro-environmental behaviors (PEBs) due to a lack of available options [37].

Studies vary on the extent of these gaps, however. The impact of attitudes on purchasing behavior related to produce and products has been found to be weak, while norms are a significant predictor [38]. Another study, which used a value–belief–norm model, found a weak connection [39]. The same value–belief–norm model also explained household energy savings and cost-effective behaviors while other studies suggest little connection between environmental concern and energy consumption [36]. Conserving energy is usually done for reasons other than concern for environmental impacts [40] and change in travel behavior is rarely due to climate concern [36,40,41]. However, other researchers found that environmental concern or knowledge (along with lower income) can lead to more PEB related to food, energy, and travel [42,43].

A dissonance between environmental attitudes and behaviors has also been found regarding air travel [44,45], and when it comes to international travel and tourism, individuals do not take the same measures to limit their environmental damage as they do around the home [46,47]. In addition, it is not uncommon that "green" measures taken at home are used as a justification of long-distance travel [48].

Factors other than climate concern are often found to be more decisive in GHG mitigation. Higher education is associated with lower personal CO_2 emissions [49], and income with higher emissions and other environmental impacts [9,49,50]. Environmental attitudes have been found to have no effect on the income–carbon relationship, except with the most climate concerned of the population [9]. Another obstacle in GHG mitigation is that PEBs related to household energy saving do not necessarily translate to lower emissions due to structural factors [51].

Even though the connection between environmental attitudes and behavior has been extensively studied, so far, few studies have paid attention to the spatial aspect. However, it is likely that environmental attitudes are manifested differently, and that they affect the behavior differently in different types of residential areas and housing types.

The aim of this study is to analyze how pro-environmental attitudes (PEAs) and residential urban zones affect PEBs regarding household energy consumption, purchasing choices of produce and clothing, and GHG emissions from travel, using results from a map-based online survey (softGIS) [52] targeting young adults living in the Helsinki Metropolitan area (HMA).

The research questions, of which the main novelty value lies on the fourth, are:

- How does the PEA affect PEB regarding household energy use, and clothing and produce purchases?
- How does the PEA affect the amount of GHG emissions stemming from local, national, and international travel?
- How do PEA, PEB, and travel-related emissions cluster geographically within the study area?
- How do these relationships differ depending on residential location?

2. Research Design

2.1. Case Area

The data collected were from inhabitants of HMA in Southern Finland. Around a quarter of the country's five million inhabitants live in the area and the fast-growing population has a high proportion of young adults. The predominance of young adults and households without children is especially pronounced in the capital city of Helsinki [53]. High demand for housing has resulted in urban sprawl, but the regional land use plan focuses on densification with development focused in the center and the densely populated corridors around the public transportation network [54]. HMA is the most affluent region in Finland and the location of the biggest and by far most diversely connected airport, thus offering conditions for frequent long-distance travel. At the same time, HMA is also the core of support of the Green Party in Finland with almost a quarter of the votes in the region going for the Green Party [55], which is likely related to a high level of environmental concern among the residents of the region. These features make the region an illustrative case for the purpose of this study.

2.2. Data Collection

The data were collected using a softGIS method, in which conventional survey questions, such as multiple choice and scaled questions, were combined with an interactive map [52,56]. The map allowed respondents to mark visited locations and answer questions pertaining to these locations. Thus, it allowed for an accurate way of measuring travel distances, frequencies, and associated emissions using geographical information systems (GIS). The survey is presented in Appendix A, in Table A1. It was targeted to individuals aged 25 to 40 years residing in the HMA municipalities of Helsinki, Vantaa, Kauniainen, and Espoo. This relatively narrow age range was chosen to minimize the effect of life course variables and generational differences. People in this age group are usually employed, are independent from their parents, and have grown up in a globalized world, with good access to information and communication technologies [15]. A random sample of 5000 individuals from the target group was drawn from the Population Register Center of Finland. Two rounds of personal letter invitations were sent to the sampled individuals in August and September 2016. After deducting incomplete responses, the response rate was 16.82% with 841 responses out of the 5000 individuals invited (see [15] for more details). The geographic distribution of the study participants' residences was similar to that of the target population: Pearson's r calculated in a 1 km hexagon grid equals 0.81, which was deemed satisfactory and close to that in other related studies [57]. The sample over-represented people with higher education (70% compared to 46% in the HMA population aged 25 to 40) and women (58% to 50%). However, as the aim of the analysis was not to estimate descriptive statistics of the population, but to estimate correlations, no weights were used in the analyses [58]. The dataset included socio-demographic variables, locations visited every day, behaviors, attitudes, values, consumption figures and background information, travel distances, estimated GHG emissions from that travel, and residential coordinates categorized into urban zones.

2.3. Data Analysis

The process of data processing and analysis is summarized in Figure 1. Subsequent steps are described in following sections, except for computing variables related to income, household type, education, and gender, which are presented in Appendix B.

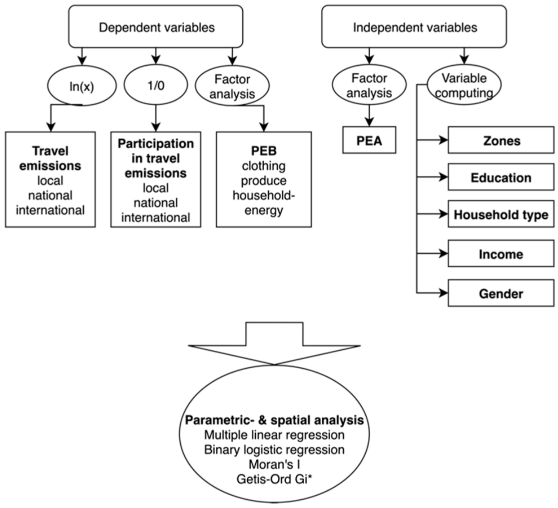


Figure 1. Flowchart of the data processing and analysis.

2.3.1. Factor Analyses

For the behavior variables, principal axis factoring was used to reduce data, with the orthogonal rotation method varimax with Kaiser normalization used to produce independent factors with no multicollinearity. Kaiser-Meyer-Olkin (KMO) and Bartlett's test was used to test the adequacy of the sampling and produced a score of 0.831, which confirmed the sampling was adequate for factor analysis. Each PEB variable had a value of 0 to 4 (a value of 0 is for never and 4 is always), which were answers to how often participants engaged in 11 behaviors (Table 1). Coefficients below 0.4 were suppressed.

Table 1. Results of factor analysis of pro-environmental behavior variables.

	Factor 1	**Factor 2**	**Factor 3**
Reduce heating in unoccupied rooms		0.757	
Reduce hot water temperature		0.542	
Switch off lights in unoccupied rooms			
Keep heating low to save energy		0.740	
Use high-efficiency appliances			
Buy organic produce			0.585
Buy local produce			0.707
Purchase items with as little packaging as possible			0.494
Buy second-hand clothes	0.534		
Choose to buy clothes according to environmental impact	0.834		
Choose to buy clothes according to ethical aspects of production	0.786		

Note: Extraction method: principal axis factoring. Rotation method: Varimax with Kaiser normalization.

The PEB factor analysis indicated that the 11 variables of environmentally significant behaviors could be reduced to just 3 factors related to clothing purchases (factor 1), household energy saving (factor 2), and produce purchases (factor 3). All three factors had an eigenvalue above 1.0 and the accumulated percentage of the explained variance was 59.917.

Each PEA variable had a value of 1 to 5 (value of 1 was "strongly disagree" and 5 was "strongly agree"), which were answers to how much participants agreed or disagreed with five statements (Table 2). Principal component analysis was used to reduce data. KMO and Bartlett's test produced a score of 0.850, which confirmed the sampling was adequate for factor analysis.

Table 2. Results of factor analysis of pro-environmental attitude variables.

Pro-Environmental Attitude Variable	Factor 1
I want to live as ecologically as possible	0.853
I am very concerned about environmental issues	0.787
I think about how I can reduce environmental damage when I go on holiday	0.760
I think about the environmental impact of services I use	0.836
When shopping, I rarely think about the environmental impact of the things I buy [reversed]	0.713

Note: Extraction method: principal component analysis.

The factor analysis confirmed that due to a high correlation between all variables, only one factor was needed. It had just over 62% of the explained variance and an eigenvalue of 3.1. The regression factor score was named the pro-environmental attitude (PEA factor score).

2.3.2. Travel-Related Urban Zones

The respondents were allocated into the following six zones depending on the coordinates of their home locations: Central pedestrian zone, the fringe of the pedestrian zone, pedestrian zones of the sub-centers, intensive public transport zone, basic public transport zone, and car zone. The zones were taken from the Travel-Related Urban Zone GIS-based classification of the Finnish Environment Institute, which divides the regions into zones depending on the distance from the center, population characteristics, public transportation infrastructure, building stock, and jobs [59].

For this study, the residential zones were merged into three categories, based on location, density, similarities in the mode of travel to work, and on having approximately the same number of respondents in each group. The central pedestrian zone and the fringe of the pedestrian zone became the pedestrian-oriented zone (33% of respondents), the pedestrian zones of sub-centers and intensive public transport zones became the public transport-oriented zone (31%), and the basic public transport zone and the car zone became the car-oriented zone (36%).

2.3.3. Travel Behavior and GHG Emissions

The variables used in analyzing travel emissions were annual per capita transportation emissions from local, domestic, and international travel. The GHG emissions were taken from the previous study of Czepkiewicz et al. [15]. They used a broad life cycle assessment (LCA) approach, accounting for both direct and indirect emissions, such as those from direct combustion, fuel and electricity production, transport infrastructure construction, and vehicle manufacturing and maintenance [15].

A large number of respondents reported zero emissions from either local, domestic, or international travel. Binary variables signifying participation or non-participation in each type of travel were computed. For those that participated in travel, the natural logarithm of emissions was used to normalize the data.

2.3.4. Spatial Statistical Analyses

The variables that were analyzed with spatial statistics were PEB factor scores related to clothing, produce and household energy, the PEA factor scores, and travel emissions from local, national, and international travel. We used two spatial statistical methods in ArcGIS 10 to identify patterns of spatial association. We used Global Moran's I statistic [60] to check whether the values were clustered in space in the whole region, and Getis-Ord Gi* to identify areas in which high or low values cluster locally [61]. Moran's I is not sensitive to some cases of local spatial association, so we computed the Gi* even in cases when Moran's I did not show a significant pattern of spatial association.

2.3.5. Multivariate Analyses

We used bivariate analysis methods, such as bar charts and Spearman correlations, and multiple regression models to analyze the relationships between explanatory variables, such as household type, gender, education, income, PEA factor scores, urban zone of the residential location, and the outcome variables: PEB factor scores related to clothing (factor 1), heating (factor 2), and produce (factor 3), and travel emissions from local, national, and international travel.

The statistical analyses were run in IBM SPSS Statistics 24. Three models for each of the PEB factor scores were prepared and the first model included the four sociodemographic variables as independent variables. In the second model, PEA factor scores were added as independent variables, and in the third model, the three residential urban zones were added too. Ordinary least squares (OLS) regression was used due to the quantitative character of the dependent variables.

Two models were calculated for each type of travel (local, domestic, and international). Binary logistic regression was used to analyze participation in emissions from travel, due to the dichotomous character of the dependent variable. OLS regression was used to analyze the amount of emissions of those who participated. By also running a binary logistic regression on participation in travel emissions, it was possible to capture which variables impacted whether a respondent had traveled in the past year and see if those same variables affected the amount of emissions. The independent variables in all models were gender, income, education level, household type, PEA factor scores, and urban zones.

3. Results and Discussion

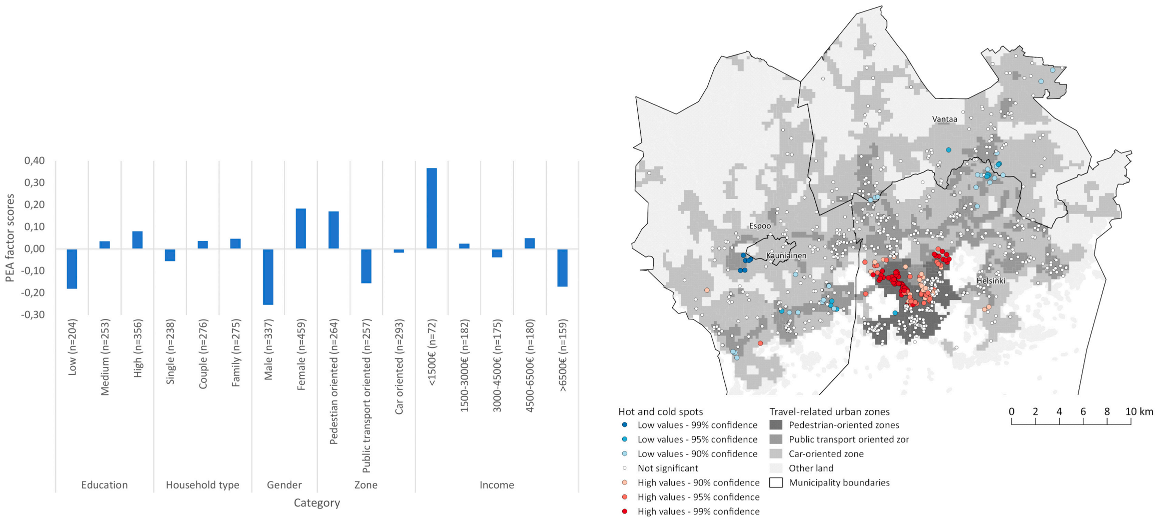
Our results show that PEAs cluster in space and have, on average, higher values in the pedestrian-oriented zones than in the car-oriented zones. We found that PEA influenced environmentally significant behaviors regarding household energy, clothing, and produce, but it did not have an effect on the amount of GHG emissions from local, national, or international travel. Residents of car-oriented zones were more likely to conserve heating at home, but less likely to purchase environmentally-friendly produce than residents of the pedestrian-oriented zones, after controlling for socio-demographic variables and the PEA. Residents of pedestrian-oriented zones generated lower emissions from local travel and were more likely to participate in emissions from international travel than residents of the remaining urban zones. In the following, we present the results of the spatial and multivariate analyses divided into three topical sections: PEAs, PEBs, and emissions from travel. Each section is followed by a short discussion that relates the results to previous studies.

3.1. Pro-Environmental Attitudes

3.1.1. Results

Those with low income tended to have higher PEA factor scores and the same can be said about those with a high level of education (Figure 2a). Although there was a correlation between income and education (r_s = o.225, $p < 0.001$, n = 847), respondents with the highest PEA scores were the most highly educated while the opposite can be said regarding income: Respondents with high income had a lower PEA score. Household size did not have a strong effect on PEA, although single people did have the lowest PEA factor scores. Women had considerably higher factor scores than men. Residents of the pedestrian-oriented zone had the highest PEA score of the three zones.

Pro-environmental attitude factor scores were significantly spatially autocorrelated (Moran's I = 0.23, $p < 0.001$). Areas with values higher than expected were located in pedestrian-oriented parts of Helsinki (Figure 2b). It is of note that the spatial association was not very strong, and residents with high factor scores lived next to residents with low factor scores, and vice-versa.



(**a**) (**b**)

Figure 2. (**a**) Mean pro-environmental attitude factor scores by education, household type, gender, zone, and income categories; (**b**) Hot spot (Getis-Ord Gi*) map of pro-environmental attitude factor scores (n = 814). Areas highlighted in red (hot spots) have a local mean higher than the global mean, and areas highlighted in blue (cold spots) have a local mean lower than the global mean scores.

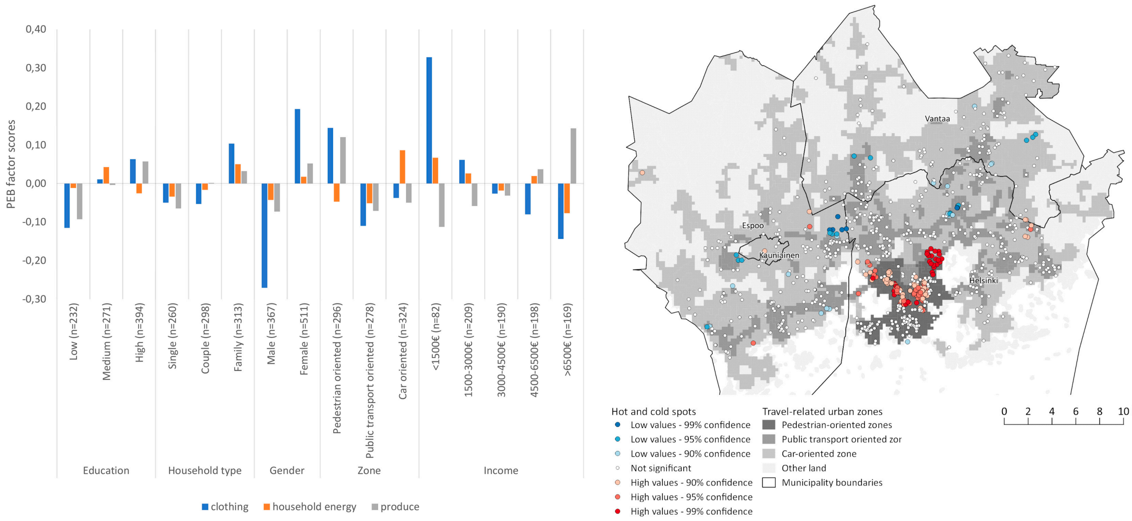
3.1.2. Discussion

In regards to our bivariate results for education level, similar trends were established [62]. The same study found that being male and having a high income were indicators of high concern, which contradicts our results. However, the high pro-environmental attitude scores of women are in line with other previous research [63,64]. Although we found clusters of high PEAs in central areas, the environmental concern of central and suburban residents has previously been found to not differ [65]. On the urban-rural scale, differences in environmental attitudes and concerns depend largely on specific issues [66], and therefore, the results of various studies might differ depending on the types of questions used. As our PEA variable consisted of quite broad terms (considerations of environmental impacts, concern for environmental issues, and wanting to live ecologically), specific environmental issues were not determined. The spatial and bivariate analysis of PEAs lays the foundation for the next two results sections of PEBs and travel emissions; it shows the distribution of our specific PEA factor scores in space, and within sociodemographic variables.

3.2. Pro-Environmental Behaviors

3.2.1. Results

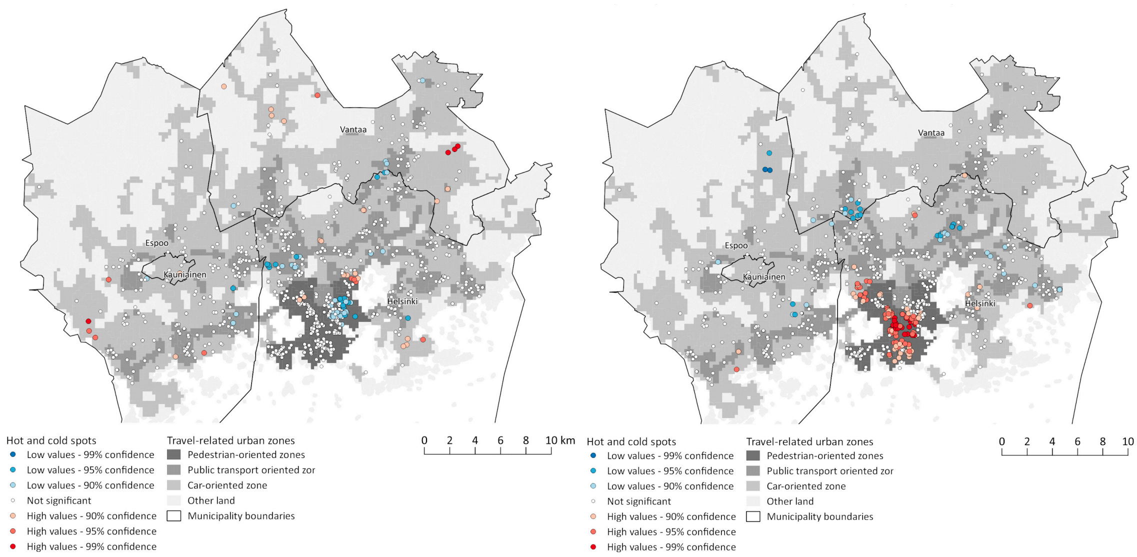
There were significant differences in the PEBs of different groups, extending to the spatial dimension. Respondents within the low education category had the lowest clothing and produce related PEB factor scores, while the high education category had the highest (Figure 3a). PEB factor scores regarding household energy use did not differ greatly depending on education level. The household type with the highest PEB factor scores in all three categories was families. Women, in general, seemed to have higher PEB scores in all three categories, although the most variance was in the clothing category. The higher the income category of the respondents, the lower their PEB factor score in the clothing category. An opposite trend was found in the produce category, where the wealthiest respondents bought the most organic, local, and package free produce. Regarding household energy, very little variance was found, but in general, the wealthier respondents were less likely to make a conscious decision of reducing household energy consumption.



(**a**) (**b**)

Figure 3. (**a**) Mean pro-environmental behavior (PEB) factor scores by categories; (**b**) Hot spot (Getis-Ord Gi*) map of factor scores of PEB factor 1: clothing (n = 831). Areas highlighted in red have values higher than the regional average, and areas highlighted in blue have values lower than the regional average.

Most notable is that the residents of the pedestrian-oriented zone had relatively high PEB factor scores related to clothing and produce purchases, which is also reflected in the spatial analysis. Local indicators of spatial association show that high values of the factors related to produce and clothing purchases cluster in central parts of the pedestrian-oriented zones of Helsinki (Figures 3b and 4b). We found no significant spatial association of the factor related to household energy and heating saving (Figure 4a and Table 3).



(**a**) (**b**)

Figure 4. (**a**) Hot spot (Getis-Ord Gi*) map of factor scores of PEB factor 2: household energy (n = 831). Areas highlighted in red have values higher than the regional average, and areas highlighted in blue have values lower than the regional average.; (**b**) hot spot (Getis-Ord Gi*) map of factor scores of PEB factor 3: produce (n = 831). Areas highlighted in red have values higher than the regional average, and areas highlighted in blue have values lower than the regional average.

Table 3. Results of the spatial analyses of PEB factor scores.

PEB Factor	Moran's I	Getis-Ord Gi*
Clothing (F1)	0.099 (p = 0.124)	Areas with the local mean higher than the global mean are located in the northern part of the pedestrian-oriented zone of Helsinki.
Household energy (F2)	−0.022 (p = 0.747)	No significant patterns of spatial association
Produce (F3)	0.070 (p = 0.272)	Areas with the local mean higher than the global mean are located in the central part of the pedestrian-oriented zone of Helsinki.

As can be seen in Table 4, the only independent variable that influenced all three PEB categories was PEA, all of which were positive and had relatively large effect sizes and impacts on R^2 (model 1 improved from $R^2 = 0.100$ to $R^2 = 0.298$ in model 1a; model 3 improved from $R^2 = 0.013$ to $R^2 = 0.203$ in model 3a).

Table 4. Multiple linear regression of clothing, household energy, and produce related pro-environmental behavior factor scores, with education level, household type, income category, gender, pro-environmental attitude, and zones as dependent variables.

PEB Model [1]		1	1a	1b	2	2a	2b	3	3a	3b
			Clothing			Household Energy			Produce	
		β	β	β	β	β	β	β	β	β
Education level	Low	-	-	-	-	-	-	-	-	-
	Medium	0.048	0.007	−0.002	0.017	−0.013	0.001	0.070	0.032	0.019
	High	0.100*	0.047	0.033	−0.023	−0.070	−0.049	0.067	0.015	−0.005
Household type	Single	-	-	-	-	-	-	-	-	-
	Couple	0.078	0.034	0.036	0.029	−0.013	−0.015	−0.007	−0.048	−0.046
	Family	0.158***	0.125**	0.139***	0.068	0.030	0.008	−0.001	−0.049	−0.027
Income category	Very low	-	-	-	-	-	-	-	-	-
	Low	−0.148**	−0.082	−0.084	−0.036	0.007	0.008	0.038	0.112*	0.111*
	Medium	−0.221***	−0.140**	−0.136**	−0.053	0.008	0.004	0.044	0.143*	0.147**
	High	−0.249***	−0.176***	−0.174***	−0.047	0.013	0.007	0.087	0.179**	0.185***
	Very high	−0.318***	−0.209***	−0.207***	−0.080	0.005	0.000	0.137*	0.274***	0.279***
Gender	Male	-	-	-	-	-	-	-	-	-
	Female	0.242***	0.163***	0.161***	0.012	−0.039	−0.037	0.076*	−0.008	−0.010
PEA			0.452***	0.447***		0.277***	0.282***		0.453***	0.449***
Zones	Pedestrian			-			-			-
	Public transport			−0.047			0.040			−0.032
	Car			−0.067			0.102*			−0.100*
R^2		0.100***	0.298***	0.311***	−0.005	0.077***	0.084***	0.013*	0.203***	0.221***
F		10.906***	31.955***	26.937***	0.534	6.036***	5.509***	2.167*	19.569***	16.936***

Notes. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$. [1] Model 1: PEB regarding clothing as a dependent variable. Education level, household type, income category, and gender as independent variables. 1a: PEA added as an independent variable. 1b: zones added as an independent variable. Model 2: PEB regarding household energy-saving as a dependent variable. Education level, household type, income category, and gender as independent variables. 2a: PEA added as an independent variable. 2b: zones added as an independent variable. Model 3: PEB regarding the purchase of produce as a dependent variable. Education level, household type, income category, and gender as independent variables. 3a: PEA added as an independent variable. 3b: zones added as an independent variable.

The wealthy residents were less likely to buy environmentally-friendly clothing (Table 4), which could be due to the purchasing of second-hand clothing being a part of our clothing measure. Education level had a significant effect on PEBs related to clothing only when attitudes and urban zones were not included (model 1), indicating that it only affects the model through attitudes. Household types affected the PEB clothing model (models 1, 1a, and 1b). Families were more likely to buy environmental, ethical, or second-hand clothing. Women had positive coefficients throughout the models, which suggest that they not only had more environmental concern, but also were more likely to take care of the kind of clothing they did purchase. There was no influence of geographical location on the models, despite spatial clustering of the factor scores, which suggests geographical clustering was due to patterns in PEAs.

Models 2, 2a, and 2b confirmed the small household energy variance found between income groups in the bivariate analysis (Figure 3a); none of the coefficients were statistically significant. A high level of income had a significantly positive effect on PEBs regarding produce and significant negative coefficients in the clothing models; the more affluent population is more likely to take care when purchasing food, but less likely to think about the environmental effects related to clothing. Residents of the car-oriented zones were more likely to save heating energy than the residents of pedestrian-oriented zones (model 2b), despite the lack of a spatial association of this variable (Figure 4a).

Gender lost significance when attitudes were added to the produce model, which suggests that it only affects the produce purchases through attitudes. Residents of the car-oriented zones were less likely to engage in PEBs related to produce purchases than residents of the pedestrian-oriented zones. Spatial autocorrelation and residual analysis was performed on models 1b, 2b, and 3b (see Appendix D, Table A6). No spatial autocorrelation was found, using global Moran's I with a threshold of $p < 0.05$, but the residuals of the clothing model (1b) showed signs of heteroskedasticity, exhibiting more variance with higher predicted values. As a result, the regression was run again using robust standard errors to see if the coefficients held their significance. The p values of these models were very similar and no coefficients lost or gained significance, indicating that our initial models predicted the significance adequately. Although OLS might not provide the best possible fit for the data, it still provided unbiased estimation of which variables influence the dependent variable, which was the primary goal of our analysis.

3.2.2. Discussion

The regression (Table 4) showed that PEA had a significant positive effect on all three PEB categories, which suggests that the attitude-behavior gap related to household energy-saving and the purchase of produce and clothing was small in our results. Value–belief–norm models have been more successful at explaining these low-cost, "good intention" behaviors than ones that have larger behavioral restrictions, such as limiting car-use [67]. Interestingly, PEAs had the least effect on household energy-related PEBs of the three categories. The effect was still quite large and significant, which is in line with other studies [39,42,43]. This could indicate that it is easier and more accessible to install secondary heating or control personal energy use in detached houses in the suburbs than in apartment buildings in the centers, as suggested by Kyrö et al. [64].

The only other variable that had a significant positive relationship with the energy PEB factor score was the residential zone, where the residents of the more sparsely populated areas were more likely to minimize household energy use. However, this is likely due to only the single-family house residents in the car-oriented zones paying directly for their heating, whereas those living in apartment buildings pay it as a part of the housing management fee or rent, having no monetary incentive to reduce usage [68,69]. Furthermore, in HMA, over 80% of households are connected to district heating, covering virtually all apartment buildings, while electricity is used for heating in the low-rise outer fringe areas [23]. Electricity is more expensive than district heating, which in turn could lead to less energy use due to monetary reasons.

The effect of zones on PEBs related to produce might be due to characteristics of the urban surroundings, which differ in availability of organic, package free, and local produce. Suburban residents may find it more difficult to practice sustainable consumption than their urban counterparts [70]. Overall, the higher the income category of respondents, the less likely they were to have high PEB scores related to household energy and clothing (Figure 3a), which is in line with several papers that state a positive correlation between income and carbon footprints related to consumption [27,49,50,71].

Multiple linear regression performed on the data split by zones showed that the relationships between PEB and PEA did not differ notably between residential zones, as the coefficients for PEA in all three zones were similar in size and significance (see Table A2 in Appendix C).

3.3. Emissions from Travel

3.3.1. Results

Participation in and amount of emissions from all travel categories increased with increased income, and the most notable difference in participation in international travel was found between respondents with very low and very high income (Figure 5). Single people had the lowest participation rates and mean annual emissions from all travel categories. Families had the highest participation rates and mean annual local travel emissions, and couples had the highest participation rates and mean annual emissions from national travel. Mean emissions from international and national travel increased with education level while local travel emissions decreased. Very little difference was found in participation in local travel between education levels. Respondents with a medium level of education had the highest participation scores, closely followed by the high education category. Women had slightly higher participation percentages than men throughout all travel categories. They had higher mean annual emissions in the national and international travel categories, while men had slightly higher emissions from local travel.

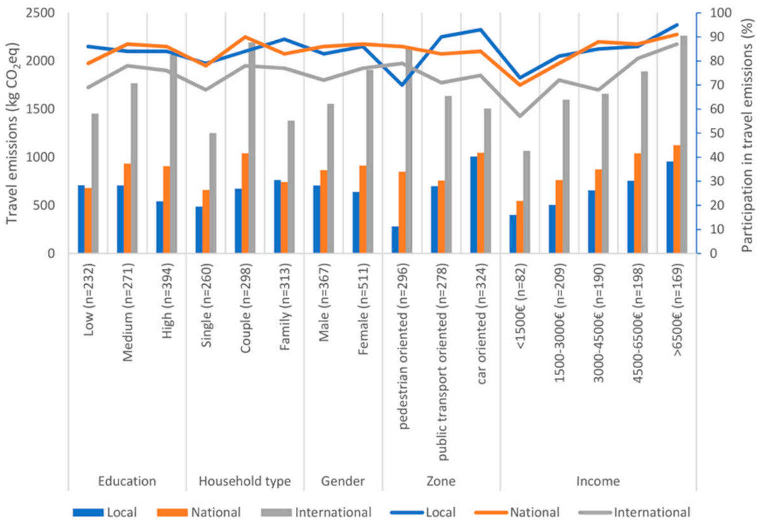
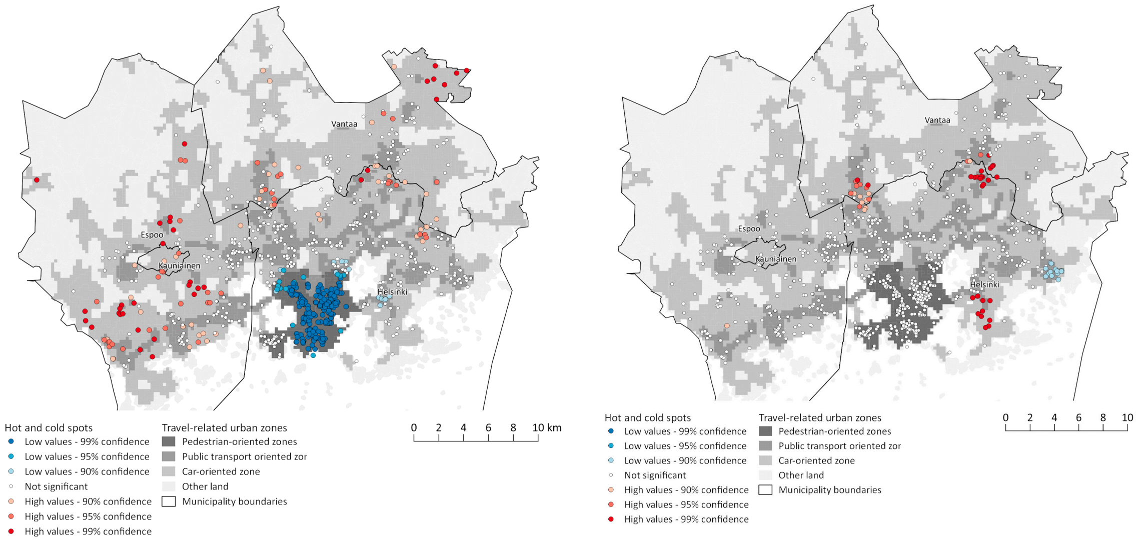


Figure 5. Mean annual local, national, and international per capita travel emissions (kg CO_2 eq) and participation (%) in emissions by gender, household type, income, education, and zone categories.

Respondents from car-oriented zones had the highest participation rates (93%) and mean annual emissions from local travel, while respondents from pedestrian-oriented zones had the lowest participation rates (70%) and mean annual emissions from local travel. On the other hand, residents of pedestrian-oriented zones had the highest participation rates and annual emissions in international travel. Participation rates and annual emissions in national travel were similar throughout the zones. Spatial clustering was the strongest in the case of emissions from local travel (Moran's I = 0.22, $p < 0.001$), and not significant in the case of domestic or international travel (Table 5), although there were significant local clusters of high emissions (Figure 6b, Figure 7).

Table 5. Results of spatial analyses of local, domestic, and international travel emissions.

Variable	Moran's I	Local Indicators of Spatial Association
Local emissions—all	0.22 (p = 0.001)	Areas with the local mean lower than the global mean are located in the pedestrian-oriented zones of Helsinki. Areas with the local mean higher than the global mean are located in the car-oriented zones of Espoo and Vantaa (Figure 6a).
Domestic emissions—all	0.023 (p = 0.775)	Areas with the local mean higher than the global mean are located in areas along the Helsinki-Vantaa border in Helsinki (Figure 6b).
International emissions—all	−0.019 (p = 0.776)	Areas with the local mean higher than the global mean are located in the pedestrian-oriented zones of Helsinki (Figure 7).



(a) (b)

Figure 6. (**a**) Hot spot (Getis-Ord Gi*) map of GHG emissions from local travel (n = 831). Areas highlighted in red have values higher than expected, and areas highlighted in blue have values lower than expected.; (**b**) hot spot (Getis-Ord Gi*) map of GHG emissions from domestic leisure travel (n = 831). Areas highlighted in red have values higher than expected, and areas highlighted in blue have values lower than expected.

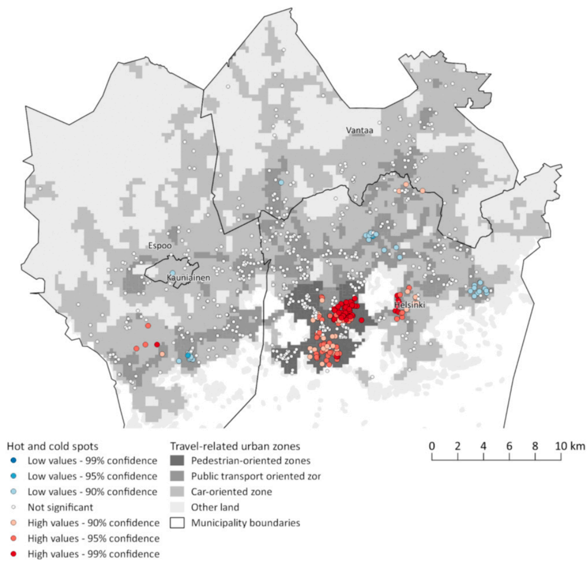


Figure 7. Hot spot (Getis-Ord Gi*) map of GHG emissions from international leisure travel (n = 831). Areas highlighted in red have values higher than the regional average, and areas highlighted in blue have values lower than the regional average.

Education level and household type did not have a statistically significant relationship to local travel, neither on the participation rates nor the amount of emissions (Table 6). High income, being a woman, and living in car-oriented zones were all positively associated with participation in local travel emissions. The largest odds ratio was found with participants of a very high income, who were more likely to participate in local travel emissions than the lowest income group.

Table 6. Binary logistic regression on participation in local travel emissions (1) and multiple linear regression on the amount of local travel emissions (1a) of local per capita annual emissions (CO_2 eq) of those participating.

Travel Model [1]		1		1a	
		B (S.E.)	**OR**	**B (S.E.)**	**β**
Education level	Low	-	-	-	-
	Medium	0.220 (0.343)	1.247	0.102 (0.150)	0.032
	High	−0.039 (0.325)	0.961	0.056 (0.144)	0.019
Household type	Single	-	-	-	-
	Couple	−0.133 (0.304)	0.874	−0.008 (0.159)	−0.003
	Family	0.106 (0.342)	1.112	−0.073 (0.161)	−0.024
Income category	Very low	-	-	-	-
	Low	0.817 (0.379) *	2.263 *	−0.107 (0.226)	−0.031
	Medium	0.471 (0.383)	1.601	0.009 (0.233)	0.003
	High	0.920 (0.426) *	2.509 *	0.250 (0.242)	0.071
	Very high	2.074 (0.560) ***	7.957 ***	0.362 (0.248)	0.103
Gender	Male	-	-	-	-
	Female	0.647 (0.253) **	1.910 **	−0.116 (0.114)	−0.039
Zones	Pedestrian	-	-	-	-
	Public transport	1.284 (0.296) ***	3.612 ***	0.870 (0.144) ***	0.276 ***
	Car	1.746 (0.338) ***	5.732 ***	1.299 (0.142) ***	0.429 ***
PEA		−0.333 (0.125) **	0.717 **	−0.100 (0.057)	−0.067
Constant		−0.050 (0.427)	0.951	5.070 (0.248) ***	
X^2 (Goodness-of-fit)[2]		11.265 (p = 0.187)			
Pseude R^2 (Nagelkerke)		0.196			
R^2				0.155 ***	
F				9.545 ***	

Notes. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$. [1] Model 1: Binary logistic regression on participation in emissions from local travel. Education level, household type, income category, gender, zones, and PEAs are independent variables. Model 1a: Multiple linear regression on the natural logarithm of the amount of yearly emissions from local travel. Education level, household type, income category, gender, zone, and PEAs are independent variables. [2] Hosmer-Lemeshow test of goodness-of-fit.

The only significant contributor to the amount of local emissions was residential location. Residents of the car-oriented zones were most likely to participate in local travel and had the highest emissions from local travel. PEAs had a negative effect on participation in emissions from local travel, but did not have a statistically significant effect on the amount of emissions.

Binary logistic regressions performed with the data split by residential zones showed that although residents with high PEA scores of all three zones were less likely to participate in local travel emissions, only the coefficients from the pedestrian-oriented zone data were statistically significant (see Table A3 in Appendix C). This suggests that those with high PEA scores living in the central pedestrian zone are able to adopt sustainable urban mobility. No statistical significance was found between PEA and international or national travel when data was split by zones (see Tables A4 and A5 in Appendix C).

Neither PEA factor scores nor residential zones had a significant relationship to domestic travel emission participation or the amount of emissions (Table 7). Single people generated significantly more emissions from travel within the country than couples and families did. Wealthier respondents were significantly more likely to participate in travel and generated more emissions. Although the amount of emissions generated by women was not significantly different to men, they were more likely to participate in national travel. Education level had no significant effect on emissions from domestic travel.

Table 7. Binary logistic regression on participation in domestic travel emissions (2) and multiple linear regression on the amount of travel emissions (2a) of domestic per capita annual emissions (CO_2 eq) of those participating.

Travel Model [1]		**2** **B (S.E.)**	**OR**	**2a** **B (S.E.)**	**β**
Education level	Low	-	-	-	-
	Medium	0.436 (0.337)	1.547	0.184 (0.123)	0.074
	High	0.302 (0.326)	1.352	0.128 (0.119)	0.055
Household type	Single	-	-	-	-
	Couple	0.402 (0.373)	1.495	−0.286 (0.124) *	−0.120 *
	Family	−0.045 (0.349)	0.956	−0.312 (0.130) *	−0.130 *
Income category	Very low	-	-	-	-
	Low	0.968 (0.382) *	2.634 *	0.052 (0.183)	0.019
	Medium	1.451 (0.429) ***	4.269 ***	0.334 (0.187)	0.123
	High	1.678 (0.486) ***	5.356 ***	0.586 (0.195) **	0.218 **
	Very high	1.906 (0.523) ***	6.726 ***	0.773 (0.202) ***	0.280 ***
Gender	Male	-	-	-	-
	Female	0.823 (0.277) **	2.277 **	−0.018 (0.093)	−0.008
Zones	Pedestrian	-	-	-	-
	Public transport	−0.590 (0.352)	0.555	−0.104 (0.113)	−0.042
	Car	−0.360 (0.367)	0.697	0.087 (0.112)	0.037
PEA		0.202 (0.134)	1.224	−0.021 (0.046)	−0.019
Constant		0.620 (0.451)	1.859	6.158 (0.201) ***	
X^2 (Goodness-of-fit)[2]		10.410 (p = 0.237)			
Pseude R^2 (Nagelkerke)		0.142			
R^2				0.057 ***	
F				3.276 ***	

Notes. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$. [1] Model 2: Binary logistic regression on participation in emissions from domestic travel. Education level, household type, income category, gender, zones, and PEAs are independent variables. Model 2a: Multiple linear regression on the natural logarithm of the amount of yearly emissions from domestic travel. Education level, household type, income category, gender, zones, and PEAs are independent variables. [2] Hosmer-Lemeshow test of goodness-of-fit.

Respondents with high income and living in pedestrian-oriented zones were more likely to participate in international travel emissions, but for those participating the amount of emissions were not significantly different from other zones or income categories (Table 8). Families had a significantly negative relationship with international travel emissions and the highly educated had a significantly positive relationship with emissions.

Table 8. Binary logistic regression on participation in international travel emissions (3) and multiple linear regression on the amount of travel emissions (3a) of international per capita annual emissions (CO_2 eq) of those participating.

Travel Model [1]		**3** **B (S.E.)**	**OR**	**3a** **B (S.E.)**	**β**
Education level	Low	-	-	-	-
	Medium	0.335 (0.267)	1.398	0.184 (0.124)	0.077
	High	0.075 (0.253)	1.078	0.368 (0.121) **	0.164 **
Household type	Single	-	-	-	-
	Couple	0.045 (0.264)	1.046	0.085 (0.128)	0.036
	Family	0.394 (0.281)	1.483	–0.377 (0.133) **	–0.163 **
Income category	Very low	-	-	-	-
	Low	1.020 (0.334) **	2.772 **	0.070 (0.188)	0.027
	Medium	0.503 (0.331)	1.653	0.113 (0.197)	0.041
	High	1.374 (0.384) ***	3.951 ***	0.258 (0.201)	0.099
	Very high	1.821 (0.433) ***	6.175 ***	0.404 (0.207)	0.154
Gender	Male	-	-	-	-
	Female	0.324 (0.207)	1.383	0.098 (0.093)	0.043

Table 8. *Cont.*

Travel Model [1]		**3** **B (S.E.)**	**OR**	**3a** **B (S.E.)**	**β**
Zones	Pedestrian	-	-	-	-
	Public transport	−0.826 (0.263) **	0.438 **	−0.204 (0.116)	−0.083
	Car	−0.556 (0.276) *	0.573 *	−0.180 (0.113)	−0.078
PEA		0.148 (0.104)	1.159	−0.018 (0.046)	−0.016
Constant		0.579 (0.373)	1.784	6.973 (0.209) ***	
X^2 (Goodness-of-fit)[2]		4.021 (p = 0.855)			
Pseude R^2 (Nagelkerke)		0.129			
R^2				0.082 ***	
F				4.298 ***	

Notes. *p < 0.05. **p < 0.01. ***p < 0.001. [1] Model 3: Binary logistic regression on participation in emissions from international travel. Education level, household type, income category, gender, zones, and PEAs are independent variables. Model 3a: Multiple linear regression on the natural logarithm of the amount of yearly emissions from international travel. Education level, household type, income category, gender, zones, and PEAs are independent variables. [2] Hosmer-Lemeshow test of goodness-of-fit.

Spatial autocorrelation and residual analysis was performed on travel models 1a, 2a, and 3a (see Appendix D, Table A6). No spatial autocorrelation was found, using global Moran's I with a threshold of $p < 0.05$, and the residuals showed no signs of heteroskedasticity; they were symmetrically distributed, showed no signs of patterns, and were clustered towards the middle of the plots.

3.3.2. Discussion

The results align with previous studies in that centrally located, pedestrian-friendly areas with mixed land use have lower levels of private car use, travel shorter distances, and thus generate less GHG emissions from local travel [7,12,72,73]. Residential location in travel-related zones was connected both to non-zero emissions and their amount, which suggests that it contributes to multiple aspects of local travel, such as car ownership, travel mode choice, and distances. PEAs, in turn, only contributed to participation in emissions: Respondents with a higher concern for the environment were more likely to rely solely on walking or cycling (Table 6). This is largely in line with previous research that suggests that PEAs are significantly related to car ownership and use [74–76]. Similarly, as in previous studies [14,21] higher incomes were related to higher GHG emissions from local travel, and the likelihood of non-zero emissions, in particular (Table 6). It likely results from differences in car-ownership, which strongly correlated with income in our sample (r_s = 0.441, p < 0.001, n = 846).

The differences in international travel emissions depending on residential location are also in line with previous studies, with residents of centrally-located dense urban areas generating higher emissions than those living farther away from the centers (Table 8) [15,56,72,77–79]. With regard to PEAs, our results are similar to those presented in a recent paper by Alcock et al. [44], where correlations were found between climate concern and PEBs, but not between environmental concern and actively refraining from air travel. Our results also reinforce the well-known link between income level and international travel [77]. The statistically significant relationship between high education and emissions from international travel, when income is controlled for, has also been previously observed [9,72]. Interestingly, in our results, higher income increased the likelihood of international travel and university education increased the amount of emissions. This suggests that income is an enabling factor, while education level contributes to traveled distances among those who can afford it, for instance, through higher cultural capital and more extensive social networks among the educated [14].

Previous studies suggest that the amount of domestic travel decreases with increasing population density and settlement size [80,81]. These studies, however, primarily compare settlements of different sizes (e.g., large cities with small towns) and not areas within one urban region. Looking at within-city differences in three Nordic cities, a previous study [82] found that distance traveled on weekends increases with distance from the city center, which is in line with the existence of clusters of high emissions from domestic travel in city outskirts in our results (Figure 6b). However, our regression shows no significant influence of urban zones on the emissions from domestic travel (Table 7). Higher income was positively associated with more domestic travel in our results, as well as in previous research [82], but we found no relationship with education level or gender, which is present elsewhere.

4. Limitations of the Study

The generalizability of the study is limited due to the single case study research design. Case studies are said to be objective due to the insights and knowledge of the researcher conducting it [83], but their generalizability is low until enough studies have been conducted [84].

The age range for the target group, 25 to 40 years, was relatively narrow. The reason this range was chosen was to minimize the effect of life course variables and generational differences, as people in this age group are usually employed, are independent from their parents, and have grown up in a globalized world, with good access to information and communication technologies [15]. The accuracy of behavior variables not related to travel might be compromised by their reliance on the respondent's perception of their behavior rather than direct observation (see Appendix A, Table A1 for the survey). An example is that instead of having access to information on the actual household energy used, respondents answered questions on how often they try to limit their use of household energy with various actions. The scope of the study is limited by the omission of business travel. This choice was made on an assumption that business trips are often involuntary and driven by different variables than leisure trips. Additionally, they constituted a very small share of the international travel emissions in our sample [15].

5. Conclusions

Previous research conducted in the study region has suggested that living in the densest urban core areas is associated with higher carbon footprints than living in suburban areas [29–31]. Similar findings have been presented by Chen et al. [32] for Sydney. Minx et al. [27] found for London that it is the spatial accumulation of wealth that is the decisive factor, not the spatial location as such. Furthermore, it is known from previous studies that PEAs do not always correlate with less energy intensive behavior [37,39–41].

Our study included local, domestic, and international travel, which has been called for by other researchers [72]. On the one hand, the results confirmed the well-established connection between compact urban form and local travel and thus suggest that land use planning may be instrumental in reducing carbon emissions by urban dwellers [7,12]. On the other hand, emissions generated from the international travel of urban dwellers are higher than those generated from their daily travel [15,72,78]. This suggests that other processes have a stronger influence on total travel-related emissions than land use planning [14]. Our results showed a correlation between residential location and international travel, but did not explain the reasons behind it. Numerous potential explanations exist, such as compensating for a lack of urban environmental quality, monetary rebounds related to car ownership, prevalence of cosmopolitan attitudes and lifestyles among urban dwellers, or influence of their higher cultural capital and extent of their social networks [34,56,72,79,85,86]. To illuminate these relationships, future studies should supplement quantitative research designs with qualitative methods to reveal motivations behind leisure travel behavior among urban dwellers [56,85].

Several mixed-methods and qualitative studies have already investigated motivations for holiday travel in the context of sustainability. They have highlighted the discrepancies between environmental concern and holiday travel and identified barriers that may hinder behavioral change in this domain [46–48]. These include, among others, high perceived benefits of leisure long-distance travel, such as its importance for social status and personal well-being [87,88]. Some travelers use PEBs in other domains of life to justify their lack of action in leisure travel [48] or may adjust their attitudes to behaviors that are beneficial and well integrated into their lifestyles, despite being aware of climate change and its factors [47]. International leisure travel has not been as often or widely discussed as an important contribution to emissions as private car travel or household energy use. This may have contributed to the awareness–behavior gap in this domain and suggest the need for education about the environmental cost of flying among the public. Future studies should further explore the discrepancy between PEA and flying, using both quantitative and qualitative methods to inform action aimed at behavioral changes. In addition, quantitative studies should use more nuanced models, which include values, beliefs, and norms, as a single PEA index can overly simplify these relationships.

Although changes in travel behavior can directly affect personal emissions, the connection between other PEBs and emissions is less clear and has even been found to be non-existent in the case of heating and energy saving, due to structural factors [51]. Household energy consumption is said to be accountable for over 25% of the personal consumption of GHG emissions in HMA [23] and is thus a key category in lowering the GHG emissions in the area. A shift away from fossil fuels in district heat production would effectively reduce the emissions due to the wide coverage of the district heating network, whereas individual incentives to engage in more energy efficient behavior could be created by installing apartment-based meters and moving from building-level heat contracts to a pay-per-use system. One of our variables for the PEB factor related to produce was organic purchases, which, compared to conventional produce, has been found to have similar global warming potential (GWP) [89].

The effectiveness of policy that relies on "green" consumers as agents of change has been doubted [90,91]. Green consumerism is still a driver of resource depletion and pollution while sustainable consumption is not. In addition, the carbon capability of individuals—that is, how equipped they are to engage in mitigation—has been found to be limited [92] and they might evaluate the environmental impact of the product incorrectly when engaging in "green" purchasing behavior [38]. In this context, it is important to acknowledge that both PEAs and PEBs are varied and complex; an attitude that emphasizes the importance of conserving biodiversity does not necessarily translate to a willingness to mitigate climate change.

More research on the carbon footprints of people with different levels of PEAs is required to fully understand the overall climate change pressure of urban residents. Such research may shed light on how much one can mitigate their climate impacts by different levels of behavioral changes, such as making pro-environmental purchasing choices of goods in the same category, spending on different consumption categories, or reducing the spending budget rather than allocating it differently. It was found that at equal income levels, the carbon footprints of HMA residents are quite similar regardless of how they spend their money as consumption is simply reallocated from one category to another [24]. Moreover, all the carbon footprints assessed for the residents of HMA were far above the remaining global per capita quota estimated for reaching even the 2 degree warming target [93]. Connecting future assessments to the 2 degree or 1.5 degree [94] target would be an important improvement for positioning the findings and making comparisons and mitigation consideration more tangible.

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Appendix A

This appendix presents relevant sections of the online softGIS survey used for data collection.

Table A1. Relevant sections of the softGIS survey.

2/14 Background information	Gender	Male
		Female
	Age	25-40
	Main occupation at the moment	Employed
		Other
		Retired
		Stay-at-home-parent/Paternity or maternity leave
		Student/Pupil
		Unemployed
	Education level	Basic education
		Upper secondary education
		Lowest level of tertiary education
		Undergraduate level
		Graduate level
		Postgraduate level
	How many hours per week do you usually spend working and studying combined?	Less than 30
		30 to 35
		35 to 40
		40 to 45
		More than 45
4/14 Household	Type of household	Couple living together
		Couple with child/children
		None
		Several people with separate budgets
		Single parent with child/children
		Single person living on her or his own
		Single person living with parents
	Household monthly income	Less than €1500
		€1500–€3000
		€3000–€4500
		€4500–€6500
		More than €6500
	How many cars are there in your household	None
		1
		2
		3
		More than 3

Table A1. *Cont.*

4/14 Household	Please indicate how much fuel your car consumes per 100 km of combined urban and highway driving	Car no. 1	less than 4
			4 to 6
			6 to 8
			8 to 10
			Above 10
			Does not apply
		Car no. 2	less than 4
			4 to 6
			6 to 8
			8 to 10
			Above 10
			Does not apply
		Car no. 3	less than 4
			4 to 6
			6 to 8
			8 to 10
			Above 10
			Does not apply
	Car no. 1 annual mileage (in kilometers)		
	Car no. 2 annual mileage (in kilometers)		
	Car no. 3 annual mileage (in kilometers)		
5/14 Home and work	How long have you lived in the Helsinki metropolitan area	Less than a year	
		One to three years	
		Three to ten years	
		More than ten years	
	Home	Please mark your main place of residence on a map	
	Work or study place	Please mark main locations	Place type
			How do you usually travel to this place?
			How often do you usually visit this place?
	What reasons were important when making decision on moving to current place of residence?	0—not at all important, 4—very important, N—not sure/not applicable. Please skip this question if it doesn't apply to you	Access to private yard
			Social life in the neighbourhood
			House or apartment size
			Housing price and cost
			Access to green areas
			Neighbourhood reputation
			Proximity to services
			Environmental impact
			House or apartment quality
			Distance from work or study place
			Distance from city centre

Table A1. *Cont.*

6/14 Local trips and services	Please mark locations that you have been frequently visiting within Helsinki metropolitan area	Please mark between 5 and 15 places. Don't worry about location accuracy. It is fine to mark just approximate location	Shopping—Grocery stores, shopping malls, markets etc.
			Daycare, kindergarten or school—Places where you bring your own children to
			Services and errands—Post office, bank, health care, personal care etc.
			Sports and active recreation—Indoor and outdoor physical activities
			Culture and sport events—Theatre, cinema, music, spectator sports etc.
			Leisure and going out—Restaurants, cafes, bars, meeting places etc.
7/14 Regional trips	Please mark locations within Finland but away from Helsinki metropolitan area, which you visited during the last 12 months	Please mark all locations that you can remember. Don't worry about location accuracy. It is fine to mark just approximate locations	Trips by car
			Trips by train
			Trips by bus
			Trips by plane
8/14 International trips	How many international trips did you make during the last 12 months?		
	If you have travelled abroad at least once during the last 12 months, please mark all the trips you can remember	Please don't worry about location accuracy. It is fine to mark just approximate location	International trips by plane
			International by boat
			International by train
			International by bus
			International by car
9/14 Pro-environmental behaviors	How often do you do the things listed below? (0—never, 1—rarely, 2—sometimes, 3—usually, 4—always, N—not sure/not applicable	Reduce heating in unoccupied rooms	
		Keep heating low to save energy	
		Buy organic produce	
		Purchase items with as little packaging as possible	
		Buy local produce	
		Buy second-hand clothes	
		Use high efficiency appliances	
		Switch off lights in unoccupied rooms	
		Choose to buy clothes according to ethical aspects of production	
		Choose to buy clothes according to environmental impact	
		Reduce hot water temperature	

Table A1. *Cont.*

11/14 Personal attitudes	Please state how much you agree or disagree with statements below (where 1 = strongly disagree, 3 = neither agree nor disagree, 5 = strongly agree)	Every now and then it is good to take a break from urban life
		Experience of different cultures is very important to me
		I feel at home wherever in the world I go
		It is easy for me to jump on a plane and go on a trip
		When shopping, I rarely think about the environmental impact of the things I buy
		I prefer spending my free time at home than going out
		There are many other things that are more important to me than housing
		I want to live as ecologically as possible
		I am not willing to limit the amount of my travel due to its environmental footprint
		I think about how I can reduce environmental damage when I go on holiday
		Exploring new places is an important part of my lifestyle
		I am very concerned about environmental issues
		I think about the environmental impact of the services I use
		Taking a holiday is very important for my wellbeing

Appendix B

The income categories of reported household incomes were computed into the following categories: Less than €1500 = very low, €1500–€3000 = low, €3000–€4500 = medium, €4500–€6500 = high, and more than €6500 = very high.

Household type was reported in the following six categories: "Several people with separate budgets", "single person living on her or his own", "single person living with parents", "couple living together", "couple with child/children", and "single parent with child/children". Categories were merged based on these three household types: Being in a childless relationship (couple, n = 298), having a child (family, n = 313), and being single and childless (single, n = 260).

Education was reported in six categories: Basic education, upper secondary, lowest tertiary, under graduate, graduate, and postgraduate. To ensure an adequate number of respondents in each category, the six categories were merged into three—low, medium, and high—based on the real-world background information they represent and the number of respondents in each group. "Under graduate" became the category "medium" (n = 271) so an education level below that became "low" (n = 232) and above became "high" (n = 394).

Gender was reported dichotomously: Men were computed into 0 and women into 1.

Appendix C

This appendix presents regressions performed on the data split by zones to see how the relationships between attitudes and behaviors vary in space. Each urban zone was regressed in a separate model. A multiple linear regression table of clothing, household energy, and produce related PEB factor scores is first presented, followed by three binary logistic regression tables on participation in local, national, and international travel emissions.

Table A2. Multiple linear regression of clothing, household energy, and produce related PEB factor scores, with education level, household type, income category, gender, and PEA as dependent variables, with data split by zones.

Zone		1	2	3	1	2	3	1	2	3
		Clothing			*Household Energy*			*Produce*		
		β	B	β	β	β	β	β	B	B
Education level	Low	-	-	-	-	-	-	-	-	-
	Medium	0.014	−0.007	0.016	−0.183	0.067	0.003	−0.085	0.035	0.014
	High	0.043	0.185*	−0.093	−0.273*	−0.016	−0.002	−0.218*	−0.043	0.156*
Household type	Single	-	-	-	-	-	-	-	-	-
	Couple	0.019	0.040	0.031	−0.074	−0.002	0.080	−0.035	−0.087	0.011
	Family	0.176**	0.106	0.112	−0.034	0.020	0.095	−0.003	−0.064	0.030
Income category	Very low	-	-	-	-	-	-	-	-	-
	Low	−0.105	−0.143	0.028	−0.132	0.254*	−0.129	0.081	−0.045	0.296**
	Medium	−0.197*	−0.219*	0.019	−0.028	0.182	−0.152	0.235**	0.084	0.130
	High	−0.116	−0.276**	−0.096	−0.102	0.167	−0.101	0.197*	0.109	0.272*
	Very high	−0.183*	−0.265**	−0.105	−0.053	0.096	−0.096	0.365***	0.240*	0.238*
Gender	Male	-	-	-	-	-	-	-	-	-
	Female	0.163**	0.187***	0.141*	0.014	−0.068	−0.066	0.085	−0.013	−0.042
Pro-environmental attitude		0.447***	0.410***	0.475***	0.299***	0.264***	0.296***	0.417***	0.484***	0.387***
R^2		0.332***	0.321***	0.290***	0.085***	0.048*	0.066**	0.252***	0.269***	0.228***
F		11.025***	10.397***	11.839***	3.143***	2.163*	2.867**	7.488***	8.089***	7.526***

Notes. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

Table A3. Binary logistic regression on participation in local travel emissions with data split by residential zones. Education level, household type, income category, gender, and PEA are dependent variables.

Zone		1		2		3	
		B (S.E.)	OR	B (S.E.)	OR	B (S.E.)	OR
Education level	Low	-	-	-	-	-	-
	Medium	−0.242 (0.599)	0.786	−0.608 (0.625)	0.544	1.055 (0.706)	2.871
	High	−0.987 (0.568)	0.373	0.070 (0.665)	1.072	1.706 (0.839)*	5.506*
Household type	Single	-	-	-	-	-	-
	Couple	−0.255 (0.410)	0.775	0.616 (0.648)	1.851	−1.182 (0.914)	0.307
	Family	−0.040 (0.474)	0.961	0.235 (0.656)	1.264	−0.691 (0.979)	0.501
Income category	Very low	-	-	-	-	-	-
	Low	0.478 (0.530)	1.612	0.982 (0.699)	2.669	1.210 (0.928)	3.352
	Medium	0.005 (0.550)	1.005	0.847 (0.677)	2.333	1.261 (0.990)	3.530
	High	0.628 (0.600)	1.873	0.737 (0.809)	2.090	2.215 (1.124)*	9.163*
	Very high	1.923 (0.755)*	6.389*	19.659 (5909.168)	344,910,941.4	1.663 (1.180)	5.276
Gender	Male	-	-	-	-	-	-
	Female	0.609 (0.356)	1.839	1.195 (0.535)*	3.303*	0.310 (0.618)	1.364
PEA		−0.422 (0.169)*	0.656*	−0.335 (0.263)	0.716	−0.179 (0.321)	0.836
Constant		1.054 (0.688)	2.868	0.822 (0.640)	2.275	1.347 (0.799)	3.845
X^2 (Goodness-of-fit)[1]		7.204 (p = 0.515)		5.511 (p = 0.702)		6.172 (p = 0.628)	
Pseudo R^2 (Nagelkerke)		0.143		0.196		0.146	

Notes. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$. [1] Hosmer-Lemeshow test of goodness-of-fit.

Table A4. Binary logistic regression on participation in national travel emissions with data split by residential zones. Education level, household type, income category, gender, and PEA are dependent variables.

Zone		1 B (S.E.)	OR	2 B (S.E.)	OR	3 B (S.E.)	OR
Education level	Low	-	-	-	-	-	-
	Medium	19.472 (4308.355)	286,194,371.8	−0.080 (0.504)	0.923	0.314 (0.580)	1.369
	High	0.714 (0.678)	2.043	0.340 (0.527)	1.404	0.307 (0.635)	1.359
Household type	Single	-	-	-	-	-	-
	Couple	1.721 (1.012)	5.589	0.394 (0.548)	1.483	−0.378 (0.760)	0.685
	Family	0.393 (0.847)	1.481	−0.262 (0.518)	0.769	−0.470 (0.687)	0.625
Income category	Very low	-	-	-	-	-	-
	Low	0.676 (0.791)	1.966	0.205 (0.642)	1.227	2.125 (0.733)**	8.374**
	Medium	19.202 (5401.501)	218,445,271.6	0.275 (0.646)	1.316	2.787 (0.870)***	16.225***
	High	1.195 (1.031)	3.302	0.324 (0.734)	1.383	4.072 (1.045)***	58.663
	Very high	0.293 (1.092)	1.341	2.323 (1.175)*	10.211*	3.050 (0.937)***	21.125***
Gender	Male	-	-	-	-	-	-
	Female	0.101 (0.612)	1.106	0.412 (0.412)	1.511	2.167 (0.626)***	8.731***
PEA		0.062 (0.294)	1.064	−0.060 (0.214)	0.941	0.410 (0.257)	1.506
Constant		0.269 (0.861)	1.309	1.126 (0.620)	3.082	−0.816 (0.654)	0.442
X^2 (Goodness-of-fit)[1]		6.586 (p = 0.582)		6.702 (p = 0.569)		6.608 (p = 0.579)	
Pseudo R^2 (Nagelkerke)		0.309		0.090		0.354	

Notes. *p < 0.05. **p < 0.01. ***p < 0.001. [1] Hosmer-Lemeshow test of goodness-of-fit.

Table A5. Binary logistic regression on participation in international travel emissions with data split by residential zones. Education level, household type, income category, gender, and PEA are dependent variables.

Zone		1 B (S.E.)	OR	2 B (S.E.)	OR	3 B (S.E.)	OR
Education level	Low	-	-	-	-	-	-
	Medium	0.206 (0.709)	1.229	0.248 (0.415)	1.282	0.558 (0.429)	1.747
	High	0.128 (0.665)	1.137	−0.004 (0.398)	0.996	0.145 (0.400)	1.156
Household type	Single	-	-	-	-	-	-
	Couple	−0.208 (0.553)	0.812	0.169 (0.397)	1.185	0.016 (0.508)	1.017
	Family	−0.274 (0.600)	0.761	0.533 (0.430)	1.704	0.519 (0.504)	1.680
Income category	Very low	-	-	-	-	-	-
	Low	2.128 (0.701)**	8.395	0.364 (0.536)	1.439	0.968 (0.592)	2.633
	Medium	0.618 (0.593)	1.856	0.100 (0.520)	1.105	0.816 (0.635)	2.261
	High	2.320 (0.824)**	10.171**	1.088 (0.647)	2.968	1.138 (0.660)	3.119
	Very high	2.272 (0.848)**	9.701**	1.341 (0.686)	3.822	1.969 (0.769)**	7.161**
Gender	Male	-	-	-	-	-	-
	Female	0.460 (0.462)	1.585	0.164 (0.320)	1.178	0.345 (0.360)	1.412
PEA		0.257 (0.219)	1.293	0.012 (0.168)	1.012	0.183 (0.185)	1.201
Constant		0.251 (0.764)	1.285	0.192 (0.511)	1.212	−0.148 (0.544)	0.863
X^2 (Goodness-of-fit)[1]		5.583 (p = 0.694)		15.270 (p = 0.54)		8.489 (p = 0.387)	
Pseudo R^2 (Nagelkerke)		0.167		0.097		0.122	

Notes. *p < 0.05. **p < 0.01. ***p < 0.001. [1] Hosmer-Lemeshow test of goodness-of-fit.

Appendix D

This appendix presents the results of the residual analysis and spatial autocorrelation of standardized residuals. Standardized predicted values and standardized residuals are plotted and global Moran's I is used to assess spatial autocorrelation, with a 1500 m fixed distance band.

Table A6. Results of residual analysis and spatial autocorrelation of standardized residuals.

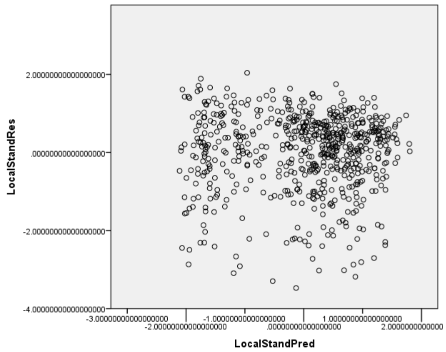
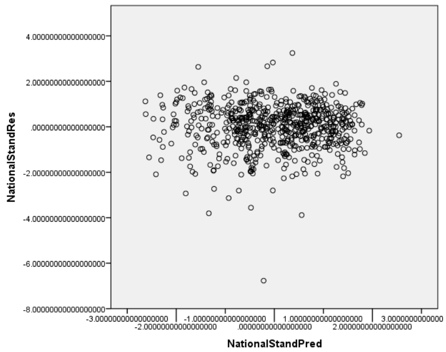
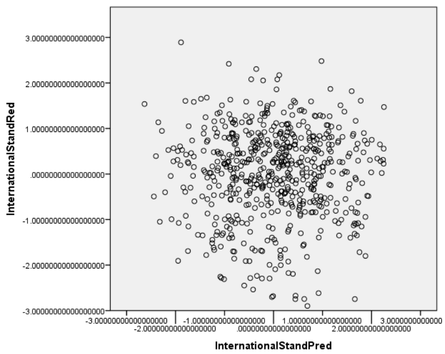
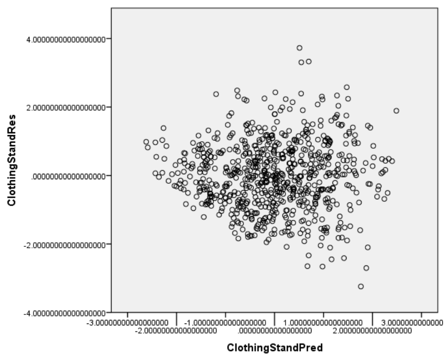
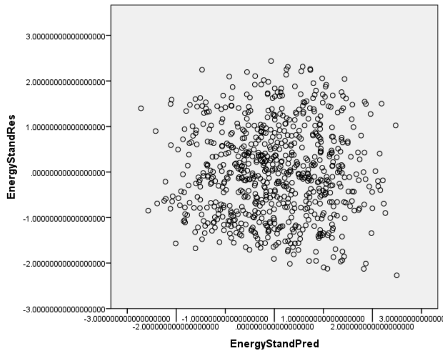
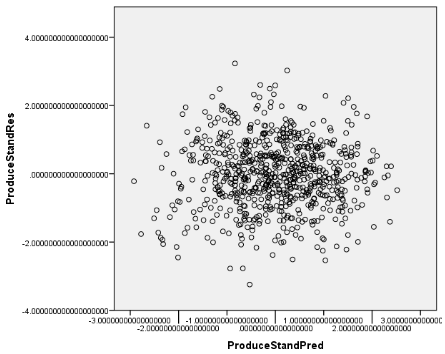
Model	Heteroskedasticity [1] (Predicted*Residual)	Spatial Autocorrelation [1] (Moran's I Z-Score, *p*-Value), 1500 m Fixed Distance Band
Local travel (1a)		1.82 (p = 0.06)
National travel (2a)		–0.33 (p = 0.74)
International travel (3a)		–1.37 (p = 0.17)
Clothing (1b)		–0.46 (p = 0.64)

Table A6. *Cont.*

Model	Heteroskedasticity [1] (Predicted*Residual)	Spatial Autocorrelation [1] (Moran's I Z-Score, *p*-Value), 1500 m Fixed Distance Band
Household energy (2b)		−0.44 ($p = 0.66$)
Produce (3b)		−0.46 ($p = 0.64$)

Note: [1] Standardized residuals used.

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