Heliyon 9 (2023) e16465

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Gender differences in spending on information and communication technology and transport fuel intensity: Evidence from Ghana

James Dickson Fiagborlo [a,*], Camara Kwasi Obeng [b], Godwin Kofi Vondolia [c]

[a] Department of Multidisciplinary Studies, Faculty of Applied Social Sciences, Ho Technical University, Ho, Ghana
[b] Department of Economic Studies, School of Economics, University of Cape Coast, Cape Coast, Ghana
[c] Department of Applied Economics, School of Economics, University of Cape Coast, Cape Coast, Ghana

ARTICLE INFO

Keywords:
Transport fuel intensity
ICT expenditure
Logistic regression
Gender
Ghana

ABSTRACT

This study estimated the effects of spending on information and communication technology (ICT) on transport fuel intensity and examined how the effects of gender on transport fuel intensity depend on spending on ICT in expanding economies. It applied restricted dependent binary logistic regression to the Ghana Living Standards Survey of 14,009 households disaggregated into 4366 women's and 9643 men's households, respectively. The main findings were that ICT expenditures complement fuel intensity in transportation and that spending on ICT has a greater impact on the fuel intensity of transportation in urban households headed by women than in those headed by men. Additionally, the study revealed that households headed by men or women consume less fuel as their income increases, age has an effect on the fuel intensity of the male and full households but not the female households, and the fuel efficiency of female-headed households improved as family size increased. Finally, only female-headed households exhibit a significant correlation between transportation fuel intensity and job status. The original value of this paper is to show that reducing spending on ICT is much more desirable for reducing the intensity of transport fuel in a gender context in expanding urban economies.

1. Introduction

Though less than one-third of the world's 3 billion poor people are men, and even fewer of these men live in metropolitan households where they are the primary breadwinners [1], in terms of trips made, time spent travelling, and distance travelled, recent studies [2–4] have shown that women travel less than men. This is because the increase in gross domestic product (GDP) in large metropolitan economies has resulted in a greater number of women working farther from home than ever before [5]. The amount of money that families in developing nations spend annually on transport fuel has skyrocketed over the last 30 years, and this is having a crippling effect on women's ability to participate broadly in society [6].

In Ghana, spending on transportation fuel has increased by more than a factor of a thousand since the 1990s, moving from GHS 5.484 in 1990 to GHS 108.266 in 2017 [7]. This represents a jump from the previous low point of GHS 5.484 in 1990. Families are reallocating their resources away from other life-enhancing commodities towards transportation activities, particularly women and

* Corresponding author.
E-mail addresses: jfiagborlo@htu.edu.gh (J.D. Fiagborlo), cobeng@ucc.edu.gh (C.K. Obeng), godwin.vondolia@ucc.edu.gh (G.K. Vondolia).

https://doi.org/10.1016/j.heliyon.2023.e16465
Received 30 December 2022; Received in revised form 16 May 2023; Accepted 17 May 2023
Available online 20 May 2023

children [4,8]. Other factors, such as mobility dynamics and the current level of infrastructure, can also have an effect on fuel consumption [9]. Additionally, a willingness to utilise technologies in a variety of industries, most notably the transportation industry, has been noted to shift the amount of money spent on travel due to their connection to urban mobility [10].

The relevant literature on gender differences is expanding, with studies [11,12] linking gender differences in relative poverty alleviation, relocation, fuelwood consumption, and climate security contexts to education. Other studies [13–16] linked gender differences in entrepreneurial ecosystems in evolving economies to information technologies [17]. asserted that ICT has become one of the vital components of modern societies, with a well-documented effect of ICT on societal activities such as political election campaigns, activism, and accountability [18]. Also, some studies [19–21] explored the impact of ICT on how women spend their time on a daily basis. However, there is a dearth of research on how the effect of gender on the intensity of transport fuel depends on spending on ICT globally. This is the gap this study aims to fill to establish key practical applications, primarily for local transport policy makers in rising urban economies.

This study looks at gender differences in spending on information and communication technology and transport fuel intensity in Ghana. It aims to examine differences in transportation fuel intensity between households headed by women and those headed by men, estimate the effects of spending on ICT on transport fuel intensity, and examine the extent to which gender effect on transportation fuel intensity depends on spending on ICT. Individual use of the internet in Ghana has risen as a proportion of the population, and mobile services have connected more than half of the Ghanaian population to the internet via their mobile phones [22]. The question that is still unanswered is how rising internet use, which is proxied by households' spending on ICT, affects transport fuel intensity in a gender context. This study defines transport fuel intensity as the amount of spending on transport fuel that is above the average yearly household transport fuel expenditure.

To answer the question above, this paper builds on [20,23], who suggested that the effects of ICT on transportation could be either substitutional or complementary, with diverse and sometimes unforeseen consequences for mobility, and hypothesised that decreasing spending on ICT will reduce fuel usage in transportation, but with different consequences for families led by men or women. Other variables such as mobility dynamics and the state of infrastructure may influence fuel consumption data in addition to gender and ICT. However, we controlled for income, which has been proxied by household spending, household size, and location, as well as the household head's marital status, whether or not the household has members over 65 years of age, and whether or not the number of individuals working in the family exceeds the mean number of workers in the home. We discussed these factors later, while we found that ICT expenditures complement fuel intensity in transportation and that spending on ICT has a greater impact on the fuel intensity of transportation in urban households headed by women than in those headed by men. We also found that households headed by men or women consume less fuel as their income increases.

This paper continues as follows: Section 2 provides the literature review; Section 3 covers the theoretical settings, i.e., the binary logit and the empirical models; Section 4 discusses the data and descriptive statistics; Section 5 analyses the results; and Section 6 offers the paper's conclusions.

2. Literature review

The literature review is done in two contexts. The first context considers transportation characteristics and ICT in Ghana. Part two covers the relevant empirical context of this paper.

2.1. Transportation characteristics and ICT in Ghana

The act of moving people, goods, or both from one location to another is referred to as transportation. ICT makes it possible for the transportation of talents and resources across geographical contexts, and mobility opens doors that lead to resources and opportunities [24]. In Ghana, the governance and organisation of transport and ICT help facilitate this mutual interaction. Since 1973, Ghana's Ministry of Transport and Communication has been in charge of the nation's transportation and communication systems. In 1997, the Ministry of Transport and Communications was split up to better accommodate the expanding fields of transportation and communications. Since that time, the Ministry of Communications has been in charge of overseeing the telecommunications sector, while the Ministry of Transport has been divided into several different departments that each concentrate on a different aspect of transportation, including the Ministries of Transport, Roads and Highways, Aviation, and Railway Development.

According to Ref. [25], even though transportation and communications are two separate subsectors, they are interrelated in every way. This is the case despite the fact that both of these fields are considered to be independent. According to the authors' point of view, there is a connection between high population levels and significant tele-densities on a regional scale. Ref. [25] emphasised that historically speaking, governments have had relatively little trouble integrating the two divisions under one ministry. According to Ref. [25], however, planning for both of the subsectors has been modified as a result of developments in mobile telephony as well as involvement from the private sector. So, despite the fact that the link is robust intellectually, it is unclear with regard to the formulation of public policy.

A recent study identified a negative link between household transport fuel use and ICT in Ghana [26], which indicates that decreasing spending on ICT should reduce the intensity of transport fuel usage. The supply of public transportation in Ghana comes from the informal sector, with bus, minibus, and taxi operators currently having the majority of market share in this industry [27]. Metro Mass Transportation (MMT) was founded in 2003 to provide faster service to travellers in urban and rural areas. It provides free bus rides to uniformed students up to the junior high school level, charges lower fares, operates on routes that private transport operators consider unattractive and unprofitable, and influences and stabilises transportation fares nationwide in support of the government's pro-poor policy [28]. The MMT also provides contract bus and school bus services, supports mass transit, and reintroduces high-occupancy vehicles [29]. Although the MMT has offered intra-city bus services since 2003, several cities still rely heavily on the minibuses run by the Ghana Private Road Transport Union (GPRTU) [30], with the motor-taxi known as Okada progressively gaining favour among Ghanaians.

2.2. Empirical context

This section looks at recent research on how women around the world use digital technologies to reach their economic goals. Ref. [16] investigated how female entrepreneurs use digital technologies. Saudi women used digital business to transform their embodied identities and lived realities rather than to evade gender embodiment online. Ref. [13] asserts that combining studies on digital innovation with women's entrepreneurship would encourage hypothesis- and empirical-based study in each field. In order to synthesise information on the challenges faced by women entrepreneurs, they conducted an "assessing review" of relevant research and literature. Another study [14,15] discovered new patterns and opportunities for future research to improve gender equity in digital technology management and use through research, theoretical developments, practises, and contemporary challenges. Ref. [11] discovered that fuelwood scarcity had an economic, social, and physical impact on women in poor countries who were responsible for household survival.

Ref. [31] used data from several waves of the Italian Household Budget Survey to do research on the consumption of fuel for private vehicles in Italy. A double-hurdle model supported by age and cohort effects revealed that older people spend significantly more on transportation fuel than younger generations. The findings support numerous economic hypotheses that predict an increase in home energy usage and a decline in transportation energy use as a result of an ageing population. Thus, because they spend more time at home, households with elderly members spend more on heating and less on the costs associated with commuting.

The double hurdle approach was also employed by Ref. [32] to look into Irish household spending on petrol and diesel. According to the study, residing in a city, taking public transport, and not owning a car are all associated negatively with spending money on petrol and diesel. Therefore, households without a car, who commute by public transportation, and who live in cities will spend less on both petrol and diesel. Contrarily, the study found a positive correlation between car ownership, occupation, household spending, and spending on petrol and diesel, showing that households with more cars, more working residents, and higher levels of household spending will spend more on petrol and diesel. According to the double hurdle model, when income levels improve, there will be a substantially greater possibility that households will spend money on the diesel market as opposed to the petrol market.

Ref. [4] used nonlinear structural equation modelling and descriptive statistics to examine gender differences in activity and travel behaviour in the Arab world. The study revealed a positive relationship between gender and travel-related activities, proving that gender significantly influences both activity participation and travel. In addition, the study found that both the number of trips and the overall amount of time spent travelling were lower for women than for men. The outcome also suggests that women make the majority of stops that serve children. The study came to the conclusion that residents' travel options are limited by their financial situation and personal obligations, despite that women use automobiles as passengers more frequently than men do.

In eight cities across three continents—Auckland, Dublin, Hanoi, Helsinki, Jakarta, Kuala Lumpur, Lisbon, and Manila— [3] examined how men and women move in urban areas. The form of transportation, the purpose of the journey, the distance travelled, and the time of departure were the main topics of the study. The findings showed that women in cities travel shorter distances and favour taxis and public transportation over their own vehicles. Another study [8] found that women use public transportation and walk more than men do. Women tend to bike less, but [8] found that in cities that encourage cycling, both sexes pedal equally. The survey found that 30–50% of active travel time was spent on public transportation. While statistics on active travel differ by age and gender, it has been discovered that gender differences increase as people get older.

Ref. [2] used the Rhône-Alpes regional household travel survey (2012–2015), which includes the second-largest urban area in France, to demonstrate that even if gender differences in employment status and access to private cars were eliminated, differences in travel behaviours between men and women would still exist because men and women do not have the same factor sensitivities. The gender differences in daily trip rate, mode of transportation, journey time, and travel purpose were examined by Ref. [33] using the nationally representative 2007 Pakistan Time-Use Survey. The study found that women travelled less, were half as mobile as men, and relied more on walking. The study also revealed that women's mobility and activities were affected by the country's social and cultural context, which perceives women as private, reclusive, and bound by family reputation. The study found a negative link between age, wealth, and married status and female mobility, implying that age, income, and marital status have reducing effect on female mobility in Pakistan.

Ref. [19] used the Latent Class Modelling (LCM) method to show how smartphones affect vehicle kilometres travelled and what that means for transportation policymaking. The study found a negative correlation between vehicle kilometre travel (VKT) and smartphone use for online shopping, active transport as the primary mode, home-to-work/school distance, and a pro-environmental attitude, suggesting that decreasing VKT requires increasing smartphone use for online shopping, active transport as the primary mode, home-to-work/school distance, and a pro-environmental attitude. However, Ref. [34] noted that price increases due to scarcity of hitherto "cheap" but non-renewable energy sources, geopolitical events influencing petroleum supply, or local regulations such as fuel taxes or congestion pricing may have an effect on telecommunications use. Nonetheless, increasing social commitment to more environmentally friendly or sustainable communication modes may have a negligible effect on telecommunications use.

There is no reason to believe that current or upcoming events will change the complementing link between travel and telecommunications, which stretches back to a number of technological advancements and political developments in the past [34]. According to Ref. [34], information exchanges through the internet about relationships, activities, and locations may improve complementarity.

Ref. [20] investigated how ICT influences how people travel. It was shown that the overall impact of travel complementarity or replacement is frequently the result of numerous factors working in different ways. Ref. [23] found that the relationship between travel and telecommunications is not one-way. The author pointed out that telecommunication can affect transportation in ways that are complementary, substitutive, and enhancing.

In order to get insight into how Greek women spend their time on various types of activities during a typical weekday or week [21], explored the function of ICT during the activities being conducted. According to the survey, women in less affluent areas preferred to use traditional forms of transportation for their everyday chores because they had less computer knowledge and there was less traffic in such locations. Furthermore, women with children tended to use electronic devices for longer periods of time when engaging in various activities on a normal day. Future scenarios showed that the activity would be more beneficial if carried out by ICT rather than physical travel in some circumstances (such as ICT accessibility, traffic conditions, and governmental incentives). In the setting of major administrative work, financial transactions, and comparative shopping during part of their shopping trips and possibly during their daily commute, "virtual mobility" offers tempting advantages for certain women.

Ref. [5] took into account development and gender studies to appreciate economic and political operations as well as how women behave and interact with transportation in their daily lives. The study encouraged a critical analysis of current transportation regulations and recommended effective ways to address the needs of women. It was concluded that a better understanding of women's needs and the issues they encounter when travelling would be helpful in developing policies that address issues other than harassment of women and that more inclusive urban access would improve conditions for women and allow them to make decisions based on their needs. This would enable social research and policy to interact, in line with [5].

According to the literature review, transportation and ICT governance, as well as their organisations, promote a symbiotic interaction. We also discovered that buses, minibuses (trotro), and taxi drivers provide 95% of urban transportation services in Ghana. The review also revealed gender variations in digital entrepreneurship, mode of transportation, trip purpose, journey distance, and departure time. It also indicated that telecommunications may have substitutional, complementary, and enhancing effects on transportation. Finally, we discovered that living in cities, taking public transportation, and not owning a car all have a negative impact on petrol and diesel expenditures, whereas car ownership, occupation, and household expenditure all have a positive impact. Clearly, the empirical research on how the effects of gender on transport fuel consumption depend on spending on ICT is weak, which is why we are interested in filling this gap to provide useful proposals, mainly for transport policy makers in rising urban economies.

3. Theoretical context: the binary logit model

This section examines the article's econometric context. The article used data from Ghana to explain gender differences in spending on information and communications technology and transportation fuel. We used a framework that allowed binary responses, assuming that the outcome variable was also binary. All binary response frameworks are built on the threshold theory. When a stimulus exceeds the agent's reaction threshold, the agent must select between two options [35]. For instance, if an agent is given the option of spending more or less on transportation fuel, their reaction threshold will produce a binary-dependent outcome y_i with zero (0) if the agent has a lower reaction threshold for spending more on transportation fuel and one (1) if the agent has a higher reaction threshold for spending less on transportation fuel. Given a set of independent factors x_i serving as potential explanations for the phenomenon in issue, the probability of observing 1 can be stated as follows:

$$p_i\left(y_i = \frac{1}{x_i\beta_i}\right) = F(x_i\beta_i) \tag{1}$$

where F is a continuous cumulative distribution function with a real value ranging from 0 to 1. β is a vector of unknown parameters. From (1), the probability of observing 0 is stated as:

$$p_i\left(y_i = \frac{0}{x_i\beta_i}\right) = 1 - F(x_i\beta_i) \tag{2}$$

Given specifications (1) and (2), the maximum likelihood estimation (MLE) is the proper econometric technique for estimating the model's parameters of interest. The MLE guarantees that heteroskedasticity is adequately taken care of [36].

An unobserved latent variable (y_i*), the choice to spend more or less on transportation fuel, has the following linear relationship with y_i:

$$y_i = x_i\beta_i + \mu_i \tag{3}$$

where μ_i is the error term which is autonomous of x_i. From (3), the observed outcome variable, which is determined by whether y_i is greater than the threshold value or not is stated in (4) as:

$$y_i = \begin{cases} 1 & \text{if } y_i* > 0 \\ 0 & \text{if } y_i* \leq 0 \end{cases} \tag{4}$$

From (4), y_i* is the threshold value for y_i, which is assumed to be normally distributed. Applying the ordinary least squares (OLS) method to estimate β in (1) will violate the homoskedasticity and normality assumptions [37]. In most famous journals, logistic or probit models are used to estimate (1) [36,38]. In this paper, we used the binary logit model to analyse gender differences in spending on ICT and transport fuel intensity. Transport fuel intensity refers to a household's yearly average spending on transport fuel, either above or below the household annual fuel budget.

The binary logistic model is used in this study because it assures that the probability estimates of the dependent variable are within the bounds of 0 and 1 and that they are non-linearly dependent on the explanatory variables [39]. To avoid compromising the probability range of 0–1, the extremely non-linear model is transformed into a linear model in the parameters by taking the logarithm of the odds ratio. The logistic function is expressed in (5) as:

$$L_i = \ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \sum \beta_j X_n \tag{5}$$

where p_i is the probability of being less fuel intensive and $1 - p_i$ is the likelihood of spending above the household annual fuel budget. L, which is linear in both X and the βs that represent the estimated parameters, is the log of the odd ratio. By differentiating with regard to x_i, one may estimate the marginal impact of each exogenous variable x_i on the likelihood that a household will decide to spend less on transportation fuel. From (5), the marginal effect is expressed in (6) as:

$$\frac{\partial p_i}{\partial x_i} = \beta_j p(1-p) \tag{6}$$

Equation (6) shows that the rate of change in probability with regard to X depends not just on βs but also on the degree of probability used to assess the change. For every unit change in X, the βs estimates the change in L. The marginal effect describes how the log odds favouring a change in the decision about transportation fuel expenditure vary by a unit.

3.1. Empirical model

This paper examines how the effect of gender on transportation fuel intensity depends on spending on ICT using the binary logit model. A household's likelihood of choosing to spend less money on transportation fuel can be predicted using the logit model, which is based on a cumulative logistic probability function. In accordance with [36,39], we expanded (5) to empirically define the logistic regression model in (7) as follows:

$$\begin{aligned} L_i = \ln\left(\frac{p_i}{1-p_i}\right) &= \beta_0 + \beta_1 h\exp_i^{ict} + \beta_2 h\exp_i^{ictsq} + \beta_3 hsize_i + \beta_4 hinc_i + \beta_5 urban_i + \\ &\beta_6 male_i + \beta_7 married_i + \beta_8 aged_i + \beta_9 owntype_i + \beta_{10} wor\ker_i + \varepsilon_i \end{aligned} \tag{7}$$

When the outcome variable is measured by a dichotomous variable, 1 indicates households that are likely to spend less on transportation fuel (LFI), and 0 indicates households that are likely to spend more on transportation fuel (MFI). The mean ICT spending (*hexp*^{ict}) and its square (*hexp*$^{\text{ictsq}}$) are the independent variables. Some of the household characteristics included in the model are household size (*hsize*), household income (*hinc*), a dummy of the setting of the households (*urban*), a dummy of the head of household's gender (*male*), a dummy of the head of household's marital status (*married*), a dummy of whether the household has members over 65 years old or not (*aged*), and a dummy of whether the household has more workers or not (*worker*). βs are the estimated coefficients, and ε is the error terms. The following section of the paper discusses the data used and provides an overview of the descriptive statistics for the variables that were employed.

4. Data

The Ghana Statistical Service's (GSS) Ghana Living Standards Survey (GLSS) was the source of data for this paper. The Statistical Service Act, 2019 (Act 1003), which replaced the Statistical Service Law, 1985, says that the Service must come up with ethical rules for collecting and using data. This guarantees the relevance, accuracy, reliability, coherence, comparability, timeliness, and integrity of the data. So, we are confident that the data used for this study was collected ethically. Every participant gave their informed consent before being recruited for the survey. For more on the service's mandates (see https://www.statsghana.gov.gh). The GLSS is the seventh round of the consumer spending survey conducted over the course of a full year in 2016–17, using a multi-stage sampling technique. Even though the survey does not usually collect information on how people travel, it does include information on how much money households spend on transportation.

For instance, the survey asked how much was spent on transportation fuel and information and communication technologies. This includes fuel for private vehicles but not public transportation. Besides food, education, water, power, and waste disposal, the data included remittances, other expenses, and rent. The survey covered 15,000 houses from Ghana's 10 administrative areas, but a 94.4% response rate reduced the sample size to 14,009 households [7]. This study used all 14,009 households to represent the household model. The women's and men's models used 4366 and 9643 disaggregated samples, respectively. This was an accurate count of female-headed and male-headed household heads who answered the transportation question. Descriptive statistics were used to determine if the LFI and MFI have analytical differences. The student t-test was used to examine ICT spending and household size. Pearson's chi-square test was used to assess categorical predictors. LFI and MFI were considered to be the same despite the regression models' predictive components. Based on the models' predictive properties, we assumed LFI and MFI were distinct.

5. Results and discussions

5.1. Descriptive statistics

This section examines a sample test of difference results and descriptive statistics. Table 1 shows that the difference in LFI and MFI due to households' spending on ICT is statistically equivalent to zero and that family size significantly extricate between LFI and MFI. Table 1 also shows that the null hypothesis that household income does not explain the difference between LFI and MFI cannot be accepted at 1%, as household income significantly differentiates between LFI and LMF.

We investigate how spending on ICT affects the effect of gender on transportation fuel intensity using data from Ghana that has been gender-separated. The assumption was that being the male family head or not influences the household's choice of being LFI or MFI. Table 1 shows a significant result at 1%, indicating that gender influences transport fuel intensity. Additionally, it is false to claim that there is no distinction between LFI and MFI based on residence because Table 1 shows a significant relationship between LFI and MFI depending on location.

We also reject the null hypothesis that, regardless of the marital status of the head of family, the LFI and MFI are equal. The findings indicate that marital status has an impact on LFI and MFI (Table 1). When LFI and MFI are compared based on whether or not a household member is above the age of 65 and whether or not more than one-third of the family works, it is believed that there is no difference (Table 1). The test shows a statistically significant difference between the LFI and MFI groups at the 1% level based on the number of employed household members above the average cut-off point and the number of members aged 65 or older.

Next, we discuss the descriptive statistics of the elements that influence TFI from the women's and men's samples. We evaluate whether the means of these characteristics were statistically distinct after computing and comparing the means of all variables for the LFI and MFI of gendered household heads. We did this by using an independent *t*-test. The null hypothesis states that the population means of the two groups (female-headed families versus male-headed households) are not statistically different. According to the alternative hypothesis, the population means of the two independent groups are statistically and significantly different. From Table 2, we observe the number of people in each group by the gender of households' heads and transport fuel intensities.

Table 2 shows that male-headed families predominate over female-headed families at all levels of fuel intensity. For example, although 4279 female-headed families spent less on transportation fuel, 8373 male-headed households spent the same. Individuals who spent more than the average amount on transportation fuel included 87 female-headed households, whereas 1270 male-headed families spent so much (Table 2). According to the distribution of household transport fuel intensity, households headed by men had higher MFI and LFI than those headed by women. Do male- and female-headed households have different transport fuel intensities? How does the effect of gender on transportation fuel spending depends on ICT? These questions are addressed later.

The categorical variables in Table 3 were examined using Pearson's chi-square distribution, while the continuous variables (ICT spending and household size) were tested using the student t-test. Compared to LFI and MFI groups, households headed by women spend more on information and communication technologies than those led by men. This is solid proof that the intensity of transportation fuel for female-headed and male-headed families varies with mean ICT spending. Table 4 in the next section shows how much the difference in LFI and MFI between households led by women and those led by men is as a result of households' spending on ICT.

5.2. Empirical results

Using disaggregated data, we explained the gender differences in spending on ICT and transport fuel intensity. The coefficients and odds ratios of the logistic models for households, women, and men are presented in Table 4. Parentheses contain robust standard errors. In the three regression models, spending on ICT is negative and statistically significant at 1%. There is no difference in direction among the three models, implying that an increase in spending on ICT has the opposite effect of reducing transportation fuel intensity. Therefore, in the three models, a unit decrease in ICT spending has a lower chance of increasing the log likelihood of being LFI versus MFI by 0.99.

Though previous studies [20,23,34] proved that inadequate transportation infrastructure may counteract the effects of spending on ICT on spending on fuel, some studies [20,34] also indicated that low-cost teleconferencing, telecommuting, teleshopping,

Table 1
Statistics of variables used in the model and test of difference for sub-sample.

Variable	Sample (14009)		MFI		LFI		
	Prop/M	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Sig. level
household ict exp.	284.867	582.641	579.584	1100.457	253.257	85.558	***
household size	4.200	2.867	5.466	3.634	4.065	2.738	***
income group	3.000	1.414	3.897	1.201	2.904	1.402	***
urban location of hh	0.430	0.495	0.427	0.495	0.430	0.495	***
male head of hh	0.688	0.463	0.936	0.245	0.662	0.473	***
married head of hh	0.552	0.497	0.808	0.394	0.524	0.500	***
housing type of hh	0.480	0.500	0.391	0.488	0.490	0.500	***
age of head of hh	0.149	0.356	0.066	0.249	0.158	0.365	***
no. of workers in hh	0.310	0.463	0.397	0.489	0.301	0.459	***

Note: *** indicates that, at 1%, the means of the related variables for LFI and MFI are significantly different. *hh* means household.

Table 2
The sample size of gender groups differentiated by TFI.

TFI	Women	MEN	TOTAL
MFI	87	1270	1357
LFI	4279	8373	12,652
TOTAL	4366	9643	14,009

Table 3
Descriptive statistics of variables used and test of difference for sub-sample (women group).

Female Sample (4,366)			MFI		LFI		
Variable	Prop/M	Std. Dev.	Prop/M	Std. Dev.	Prop/M	Std. Dev.	Sig. level
household ict exp.	218.050	575.940	709.063	886.077	208.066	218.050	***
household size	3.398	2.147	4.069	2.401	3.384	3.398	***
income group	2.836	1.387	4.103	1.182	2.810	2.836	***
urban location of hh	0.486	0.500	0.586	0.495	0.484	0.500	***
married head of hh	0.209	0.407	0.402	0.493	0.205	0.404	***
housing type of hh	0.555	0.497	0.402	0.493	0.558	0.497	***
age of head of hh	0.207	0.405	0.138	0.347	0.208	0.406	***
no. of workers in hh	0.217	0.412	0.483	0.503	0.211	0.408	***
Male sample (9,643)							
household ict exp.	315.12	583.168	570.14	1113.37	276.352	315.12	***
household size	4.564	3.071	5.561	3.685	4.412	4.564	***
income group	3.074	1.42	3.883	1.201	2.951	3.074	***
urban location of hh	0.404	0.491	0.417	0.493	0.402	0.490	***
married head of hh	0.707	0.455	0.836	0.370	0.687	0.464	***
housing type of hh	0.447	0.497	0.391	0.488	0.455	0.498	***
age of head of hh	0.123	0.328	0.061	0.240	0.132	0.339	***
no. of workers in hh	0.352	0.478	0.391	0.489	0.346	0.476	***

Note: *** indicates that, at 1%, the means of the related variables for LFI and MFI are significantly different. *hh* means household.

telebanking, and telemedicine are likely to replace travel possibilities for technologically savvy households.

In the full and male models, the estimation of household size is negative and statistically significant, but it is positive and insignificant in the female model. Compared to full and male-headed households, households headed by women are more likely to be LFI versus MFI. Precisely, an increase of one unit in the size of a family with a female head increases the likelihood of being LFI versus MFI by 1.084, other things being equal. Contrarily, an increase of one unit in the size of households, besides those headed by men, reduces the log odds of being LFI by 0.97 and MFI by 0.96, respectively. These findings are consistent with a previous study [31], which found that an additional household member increases the chance of a female-headed household pooling cars, thereby raising the log odds of being LFI than MFI, while the dead end of sharing and pooling cars may make male-headed households or total households less likely to be LFI than MFI.

In all three regression models, the income indicator variables from Table 4 are positive and significant drivers of the transport fuel intensities. The results show that, compared to being in an upper-income household, being in a lower-income household increases the log odds of being LFI than MFI by 7.907, 7.456, and 8.016, respectively. Additionally, the results show that compared to being in an upper-income home, being in a lower-middle-income household increases the log odds of being LFI than MFI by 2.680, 4.498, and 2.614, respectively, in all models. Once more, the findings show that, in comparison to being in an upper-income home, being in a middle-income household increases the log odds of being LFI than MFI by 1.893, 3.214, and 1.838, respectively, for all models. The results show that, in comparison to an upper-income household with a female head or a male head of household, being in an upper-middle-income household increases the log odds of being LFI than MFI by 1.637, 1.969, and 1.622, respectively, for all models.

According to the findings, female heads are more likely to be LFI than male heads across all indices of wealth. The outcome is not unexpected because wealth and female mobility have been found to have a negative relationship in the past [33]. This demonstrates that money has a detrimental impact on female mobility and, consequently, fuel expenditure. A further indication that households are becoming MFI is the fact that the effects of spending less on fuel become smaller as households move from lower to higher income levels. This result is consistent with a prior study [32], which revealed that when income levels rise, there is a greater possibility that households will spend money on diesel as opposed to petrol. According to economic theory, goods are deemed “normal” where there is more spending on them and inferior where there is less spending as income rises. These findings imply that transportation fuel is an economic good.

Only in the male models is the urban variable’s coefficient positive and statistically significant, implying that urban households headed by men are more likely to be LFI than MFI when related to both full and female-headed households. Specifically, the log probabilities of being LFI as opposed to MFI are increased by 1.197 when living in a city. To explore the traversing effects of location and ICT spending on transport fuel intensities, an interaction term was added to the model. The interaction between urban and ICT spending was positive and significant in all three models, showing that, though urbanity had no effect on fuel intensities in the full and female models, there was a statistically significant urban effect among households with ICT spending. Table 4 shows that ICT spending

Table 4
Estimated logistic coefficient of full, women and male models of transport fuel intensity.

Variables	Model[f]	Model[w]	Model[m]	(EXP(B))[f]	(EXP(B))[w]	(EXP(B))[m]
ICT	−0.005[a]	−0.005[a]	−0.001[a]	0.995[a]	0.997[a]	0.999[a]
	(0.002)	(0.002)	(0.000)	(0.002)	(0.002)	(0.000)
ICT × ICT	2.89e-06 [b]	2.92e-06 [b]	2.19e-07[c]	1.000	1.000 [b]	1.000[c]
	(1.41e-06)	(1.31e-06)	(1.27e-07)	(1.41e-06)	(1.31e-06)	(1.27e-07)
Men	−2.200[a]			0.111[a]		
	(0.305)			(0.034)		
Men × ICT	0.004 [b]			1.004 [b]		
	(0.002)			(0.002)		
Men × ICT × ICT	−2.68e-06[c]			1.000[c]		
	(1.42e-06)			(1.42e-06)		
Urban	−0.038	−0.0403	0.180[c]	0.963	0.961	1.197[c]
	(0.404)	(0.415)	(0.104)	(0.389)	(0.399)	(0.124)
Urban × ICT	0.003 [b]	0.004 [b]	0.001 [b]	1.003 [b]	1.004 [b]	1.001 [b]
	(0.002)	(0.002)	(0.000)	(0.002)	(0.002)	(0.000)
Urban × ICT × ICT	−2.78e-06[c]	−2.89e-06 [b]	−2.02e-07	1.000*	1.000 [b]	1.000
	(1.42e-06)	(1.31e-06)	(1.27e-07)	(1.42e-06)	(1.31e-06)	(1.27e-07)
Men × Urban	0.227			1.255		
	(0.416)			(0.522)		
Men × Urban × ICT	−0.003[c]			0.997[c]		
	(0.002)			(0.002)		
Men × Urban × ICT × ICT	2.58e-06[c]			1.000[c]		
	(1.42e-06)			(1.42e-06)		
Household size	−0.030 [b]	0.081	−0.035[a]	0.970 [b]	1.084	0.965[a]
	(0.012)	(0.052)	(0.011)	(0.011)	(0.057)	(0.011)
Lower income	2.068[a]	2.009[a]	2.081[a]	7.907[a]	7.456[a]	8.016[a]
	(0.168)	(0.623)	(0.171)	(1.329)	(4.645)	(1.373)
Lower middle income	0.986[a]	1.504[a]	0.961[a]	2.680[a]	4.498[a]	2.614[a]
	(0.111)	(0.473)	(0.115)	(0.298)	(2.126)	(0.301)
Middle income	0.638[a]	1.167[a]	0.609[a]	1.893[a]	3.214[a]	1.838[a]
	(0.096)	(0.383)	(0.099)	(0.181)	(1.231)	(0.182)
Upper middle income	0.493[a]	0.677 [b]	0.484[a]	1.637[a]	1.969 [b]	1.622[a]
	(0.084)	(0.308)	(0.088)	(0.137)	(0.606)	(0.142)
Not married	0.471[a]	0.655[a]	0.460[a]	1.601[a]	1.925[a]	1.584[a]
	(0.083)	(0.239)	(0.089)	(0.133)	(0.460)	(0.142)
Age above 65 years	0.793[a]	−0.030	0.881[a]	2.210[a]	0.970	2.414[a]
	(0.117)	(0.339)	(0.127)	(0.258)	(0.329)	(0.307)
House owner	−0.354[a]	−0.836[a]	−0.310[a]	0.702[a]	0.433[a]	0.734[a]
	(0.072)	(0.249)	(0.075)	(0.050)	(0.108)	(0.055)
Workers in the home	0.035	−0.827[a]	0.106	1.036	0.437[a]	1.112
	(0.067)	(0.235)	(0.070)	(0.069)	(0.103)	(0.077)
Constant	3.812[a]	3.582[a]	1.604[a]	45.228[a]	35.942[a]	4.973[a]
	(0.319)	(0.539)	(0.140)	14.442	(19.364)	(0.697)
N	14,009	4366	9643	14,009	4366	9643
Log pseudo/likelihood	−3725.112	−351.796	−3359.353	−3725.112	−351.796	−3359.353
Pseudo R^2	0.164	0.176	0.106	0.164	0.176	0.106

Robust standard errors in parentheses [a] $p < 0.01$, [b] $p < 0.05$, [c] $p < 0.1$ NB: f = full model; w = women model; m = men model.

escalates the log odds of being LFI versus MFI by 1.003, 1.004, and 1.001 for urban households, as well as those headed by women or men. The result indicates that ICT expenditures have a greater impact on transport fuel intensities for urban households with female heads than those with male heads. According to studies [2–4], city women travel less than men in terms of trips, time, and distance, which may reduce their travel expenses. Women in urban areas also walk and use public transportation more than men, which may reduce their fuel costs [8].

The study reveals that male household leaders influence the likelihood of being LFI versus MFI. In particular, the male gender decreased the log likelihood of being LFI rather than MFI by 0.111 (Table 4). Male household leaders are more likely to work to support their families, making them more mobile and fuel consumers. However, to appreciate the intersecting effects of gender and ICT expenditure on transport fuel intensities, an interaction component was included in the model. The interaction coefficient was positive and significant, indicating that, while men who did not spend money on ICT were less likely to be LFI than women, there was a statistically significant gender effect among households with ICT spending. Specifically, Table 4 shows that ICT expenditure intensifies the log odds of being LFI versus MFI by 1.004 for men compared to women. This result refutes past research [4], but it is supported by Ref. [9], who found that mobility dynamics and infrastructure can also alter fuel consumption data. Ref. [10] also stated that a proclivity to use technologies in other businesses, most notably the transportation industry, may lead to shifts in travel spending owing to urban mobility and not gender.

The household head's marital status is a significant positive predictor of LFI in all three models. In each of the three models, singlehood is more likely to increase LFI than MFI. When unmarried, the log odds of being LFI rather than MFI increase by 1.637, 1.969, and 1.622, respectively, in the full, female, and male models. The female-headed model is more affected by marital status than the male-headed and aggregated models. This conclusion is likely because an unmarried female family head may have dependant children, making walking impractical according to Ref. [33] yet needing expensive forms of transportation according to Refs. [4,8]. Nonetheless, unmarried women with children are more likely to carpool, increasing the likelihood of being LFI than MFI.

Table 4 shows that owning a home is negative and significantly linked to being LFI than MFI in all three models. In all three models, the result means that if someone owns their own home instead of renting, they are less likely to be LFI than MFI. In the full, female, and male models, respectively, living in one's own home against renting lowers the log odds of being LFI by 0.702, 0.433, and 0.734, other things being equal. The results are consistent with earlier studies [40,41], which showed a relationship between the location of a household's residence and the cost of public transportation, particularly for middle-to low-income groups. In the male model, living in one's own home reduces the chance of being LFI more than in the aggregate model or the female model. Despite the male model's higher LFI for homeowners versus renters, the aggregated and female models indicate a smaller effect size for the variable. The results reveal that people's housing works as a measure of their life-cycle status, absorbing some of the less relevant impacts of family size and repeating the home-ownership effect in the model with a female head of household.

In two models, the dummy variable for age is positively and significantly correlated with whether or not a person is LFI. In particular, our findings indicate that having a family head older than 65 increases the log likelihood of being LFI than MFI by 2.210 and 2.414, respectively, in both full and male models. This finding is consistent with the findings of [31], who discovered that because the elderly households spend more time at home, they spend more on heating and less on transportation. In contrast, we found that age is a negative and insignificant factor in determining whether households with female heads older than 65 are LFI or MFI, despite the fact that a previous study [31] did not support the negative effect of age on transportation fuel expenditure.

In addition to the aforementioned findings, we also hypothesised that households with more than one-third of their members employed would have a higher chance of being LFI than MFI. Table 4 shows that job status does not have a positive effect on TFI, but it does make it less likely that a female household is LFI instead of MFI by a factor of 0.437. This indicates a correlation between the status of employment and transportation fuel intensity. This result is consistent with [31], who discovered a negative relationship between employment status and energy costs, but inconsistent with [32], who discovered a positive relationship between employment and energy consumption. As countries get better and more jobs open up, these results will be very useful, especially for people who make decisions about local transportation in growing cities.

5.3. Average marginal effects

The model's three-way interaction is examined to determine how the effect of gender on transport fuel consumption is influenced by household ICT expenditures and location. Appendix 1 Figure A1 illustrates the average marginal effects of how the variance in the effect of gender between rural and urban households changes with ICT spending. We notice that the difference in effects of gender between rural and urban households is initially positive but then declines and becomes negative after GHS 300 in ICT expenditures are made, and rises later after spending GHS 700 on ICT. This result implies that any policy aimed at reducing the intensity of transport fuel expenditure should consider subsidising households that are technologically savvy.

6. Concluding remarks and policy implications

This study examined gender differences in ICT spending and transport fuel intensity in developing economies, as well as the relationship between ICT spending and gender effects on transport fuel intensity. The study used three logistic models to analyse aggregated and disaggregated household data. The main findings are that ICT expenditures complement fuel intensity in transportation. Spending on ICT has a greater impact on the fuel intensity of transportation in urban households headed by women than in those headed by men. The average marginal effects show that the difference in gender effects between rural and urban households is initially positive, then decreases and becomes negative until ICT expenditures exceed GHS 300, and then increases after GHS 700. This implies that initiatives to reduce the expenditure of fuel in transportation should include price support for technologically savvy urban households headed by women. Additionally, the study reveals that households headed by men or women consume less fuel as their income increases. Age has an effect on the fuel intensity of the male and full households, but not the female households. In contrast to male-headed and full households, the fuel efficiency of female-headed households improved as family size increased. Homeownership influences fuel efficiency, and unmarried individuals consume less fuel than married individuals. Finally, only female-headed households exhibit a significant correlation between transportation fuel intensity and job status.

The complementary relationship between ICT spending and transport fuel intensity, as well as the fact that female-headed households in lower income brackets consume less fuel than male-headed households, has policy implications for sustainable transportation in developing nations. Considering that taxes account for 20% of cell phone prices in Ghana, policymakers should consider reducing the Communication Service Tax (CST) and customs taxes on mobile data, handsets, and smartphones in order to eliminate barriers to teleconferencing, telecommuting, teleshopping, telebanking, and telemedicine and reduce transit fuel intensity. According to this study, any price subsidy that restricts the ICT spending of households to GHS 300 should raise the difference in effects of gender on transport fuel intensity between rural and urban households.

There are some restrictions on this paper. The cross-sectional nature of the data does not make it possible to examine how gender differences in ICT spending and transportation fuel intensity have changed over time. In the meantime, using cross-sectional panel approaches on longitudinal data might reveal some dynamic effects of ICT spending on the gender-specific fuel intensity of transportation. We encourage future research to use cross-sectional panel approaches on longitudinal data to assess the relationship between ICT spending and fuel intensity in the context of gender. It is also probable that factors like movement patterns and the health of the infrastructure may have some impacts on the data on fuel use. Future scholars ought to take these into account when exploring how gender effect on transport fuel intensity depends on spending on ICT.

Funding

No funding was received for conducting this study.

Financial interest

The authors have no relevant financial or non-financial interests to disclose.

Author contribution statement

James Dickson Fiagborlo: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Camara Kwasi Obeng: Conceived and designed the experiments; Analyzed and interpreted the data.

Godwin Kofi Vondolia: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Data availability statement

Data associated with this study has been deposited at https://www2.statsghana.gov.gh/nada/index.php/catalog/97.

Additional information

No additional information is available for this paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Acknowledgements

The authors thank the Ghana Statistical Service for granting access to use the GLSS7 data for this study. Again, we acknowledge how remote communications from anonymous referees and the Journal editors have also improved the article.

Appendix 1

fx1

Figure A1: Average marginal effects of how the difference in the effect of gender on transport fuel intensity between rural and urban households, changes with ICT spending.

References

[1] F. Farioli, T. Dafrallah, Gender issues of biomass production and use in Africa, Bioenergy Sustain. Dev. Africa (2012) 345–361.
[2] N. Havet, C. Bayart, P. Bonnel, Why Do Gender Differences in Daily Mobility Behaviours Persist Among Workers? Transportation Research Part A: Policy and Practice vol. 145, 2021, pp. 34–48.
[3] W.S. Ng, A. Acker, Understanding urban travel behaviour by gender for efficient and equitable transport policies, in: International Transport Forum Discussion Paper, 2018.
[4] W. Elias, J. Benjamin, Y. Shiftan, Gender differences in activity and travel behaviour in the Arab world, Transport Pol. 44 (2015) 19–27.
[5] M. Thynell, The quest for gender-sensitive and inclusive transport policies in growing Asian cities, Soc. Incl. 4 (3) (2016) 72–82.
[6] G. Pourhashem, G. Lugano, Gender and generation effects on perception of value of travel time and mode choice, in: Proceedings of 8th Transport Research Arena TRA, 2020, pp. 27–30.
[7] Ghana Statistical Service, Ghana Living Standards Survey Round 7- Main Report, Ghana Statistical Service, 2017.
[8] R. Goel, O. Oyebode, L. Foley, L. Tatah, C. Millett, J. Woodcock, Gender differences in active travel in major cities across the world, Transportation (2022) 1–7.
[9] F. Alonso, M. Faus, B. Cendales, S.A. Useche, Citizens' perceptions in relation to transport systems and infrastructures: a nationwide study in the Dominican Republic, Infrastructures 6 (11) (2021) 153.
[10] F. Alonso, M. Faus, M.T. Tormo, S.A. Useche, Could technology and intelligent transport systems help improve mobility in an emerging country? Challenges, opportunities, gaps and other evidence from the caribbean, Appl. Sci. 12 (9) (2022) 4759.
[11] V.S. Waris, P.C. Antahal, Fuelwood scarcity, poverty and women: some perspectives, ISOR J. Hum. Soc. Sci. 19 (8) (2014) 21–33.
[12] Y. Zhu, S. Shibasaki, R. Guan, J. Yu, Poverty alleviation relocation, fuelwood consumption and gender differences in human capital improvement, Int. J. Environ. Res. Publ. Health 20 (2) (2023) 1637.
[13] J. Sundermeier, L. Wessel, E.J. Davidson, Can Digital Innovation Alter the Landscape of Women's Entrepreneurship? Towards a Research Agenda, ICIS, 2018.

[14] E. Ughetto, M. Rossi, D. Audretsch, E.E. Lehmann, Female entrepreneurship in the digital era, Small Bus. Econ. 55 (2020 Aug) 305–312.
[15] P. Paoloni, G. Secundo, V. Ndou, G. Modaffari, Women entrepreneurship and digital technologies: Towards a research genda, in: Advances in Gender and Cultural Research in Business and Economics: 4th IPAZIA Workshop on Gender Issues 2018, Rome, Italy, vol. 4, Springer International Publishing, 2019, pp. 181–194.
[16] M. McAdam, C. Crowley, R.T. Harrison, Digital girl: Cyberfeminism and the emancipatory potential of digital entrepreneurship in emerging economies, Small Bus. Econ. 55 (2020 Aug) 349–362.
[17] S.A. Selmi, Use of ICT to promote literacy in sub-Saharan Africa, Am. J. Multidiscipl. Res. Innov. 2 (1) (2023) 49–64.
[18] M.B. Priebe, Gender All the Way Down: Proposing a Feminist Framework for Analysing Gendered Climate Security Risks, Harvard University, 2023. Doctoral dissertation.
[19] S. Jamal, M.A. Habib, N.A. Khan, Does the use of smartphone influence travel outcome? An investigation on the determinants of the impact of smartphone use on vehicle kilometres travelled, Transport. Res. Procedia 25 (2017) 2690–2704.
[20] P.L. Mokhtarian, G. Tal, Impacts of ICT on travel behaviour: a tapestry of relationships, in: The Sage Handbook of Transport Studies, vol. 14, 2013, pp. 241–260.
[21] A. Polydoropoulou, A. Tsirimpa, Women's time use with ICT and physical travel in Greek urban and rural areas, SPOUDAI-J. Econ. Bus. 62 (1–2) (2012) 72–91.
[22] Global System for Mobile Communication, Country overview: Ghana driving mobile-enable digital transformation. Global System for mobile Communication. https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2017/10/Ghana-Summary-Web-links.pdf, 2017.
[23] I. Salomon, Telecommunications and travel relationships: a review, Transport. Res. Gen. 20 (3) (1986) 223–238.
[24] W. Schulz, Reconstructing mediatisation as an analytical concept, Eur. J. Commun. 19 (1) (2004) 87–101.
[25] D.K. Okyere, M. Poku-Boansi, K.K. Adarkwa, Connecting the dots: the nexus between transport and telecommunication in Ghana, Telecommun. Pol. 42 (10) (2018) 836–844.
[26] J.D. Fiagborlo, Essays on Transport Mode Choice, ICT and Fuel Expenditures in Ghana, Doctoral thesis, University of Cape Coast, Cape Coast, 2020.
[27] A. Kumar, E.A. Kwakye, Z. Girma, What works in private provision of bus transport services—case study of Accra and Addis Ababa, in: 11th Conference of CODATU, 2004.
[28] D. Birago, S.O. Mensah, S. Sharma, Level of service delivery of public transport and mode choice in Accra, Ghana, Transp. Res. Part F: Traffic Psychol. Behav. 46 (2017) 284–300.
[29] E. Agyemang, Mode choice for long distance trips: evidence from the greater Accra metropolitan area of Ghana, J. Transport Geogr. 64 (C) (2017) 150–157.
[30] A.M. Abane, Travel behaviour in Ghana: empirical observations from four metropolitan areas, J. Transport Geogr. 19 (2) (2011) 313–322.
[31] R. Bardazzi, M.G. Pazienza, Ageing and private transport fuel expenditure: do generations matter? Energy Pol. 117 (2018) 396–405.
[32] J. Eakins, An application of the double hurdle model to petrol and diesel household expenditures in Ireland, Transport Pol. 47 (2016) 84–93.
[33] M. Adeel, A.G. Yeh, F. Zhang, Gender inequality in mobility and mode choice in Pakistan, Transportation 44 (2017) 1519–1534.
[34] P.L. Mokhtarian, Telecommunications and travel: the case for complementarity, J. Ind. Ecol. 6 (2) (2008) 43–57.
[35] P. Kau, L. Hill, A threshold model of purchasing decisions, J. Market. Res. 9 (3) (1972) 264–270.
[36] J.M. Wooldridge, Econometric Analysis of Cross Section and Panel Data, MIT press, 2010.
[37] J.S. Long, J. Freese, Regression Models for Categorical Dependent Variables Using Stata, Stata press, 2006.
[38] J.L. Horowitz, N.E. Savin, Binary response models: Logits, probits and semiparametrics, J. Econ. Perspect. 15 (4) (2001) 43–56.
[39] D.N. Gujarati, Basic Econometrics, Prentice Hall, 2022.
[40] Y. Dewita, M. Burke, B.T. Yen, The relationship between transport, housing and urban form: affordability of transport and housing in Indonesia, Case Stud. Transp. Policy 8 (1) (2020) 252–262.
[41] D. Liu, M.P. Kwan, Z. Kan, Y. Song, An integrated analysis of housing and transit affordability in the Chicago metropolitan area, Geogr. J. 187 (2) (2021) 110–126.