

Original Research

Does Internet Access Contribute to Residents' Pro-Environmental Behavior? Evidence from China

Ningze Yang^{1,2}, Xuetao Sun³, Yiwei Wang⁴, Yongliang Yang^{1,2*}

¹School of Economics and Management, Zhejiang Sci-Tech University, Zhejiang, China

²Silk and Fashion Culture Research Center of Zhejiang Province, Hangzhou, China

³Institute of Rural Development, Shandong Academy of Social Sciences, Jinan, China

⁴School of Economics, Zhejiang University of Technology, Zhejiang, China

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Abstract

Residents' pro-environmental behavior (PEB) is vital for solving environmental pollution. This paper uses a micro sample of 10993 respondents from the Chinese General Social Survey. Propensity score matching was used to assess the effect of Internet access on residents' PEB, and the study finds a significant positive impact on private-sphere PEB and public-sphere PEB. This fundamental conclusion still holds after utilizing the instrumental variable method, changing the dependent variable, core explanatory variable, and the econometric model. Heterogeneous analysis finds that Internet access has a more significant positive impact on private-sphere PEB for elderly, women, low educated and rural residents. Internet access has a more significant positive impact on public-sphere PEB for the middle-aged, women, higher educated, and urban residents. The mediating test suggests that Internet access promotes residents' PEB and raises the overall level of residents' environmental awareness through the mediating factor of residents' PEB. This paper provides the theoretical and empirical basis that Internet technology can promote PEB at the microlevel, which emphasizes the positive impact of information and communications technology on eco-environmental improvement.

Keywords: internet access, private-sphere pro-environmental behavior, public-sphere pro-environmental behavior, environmental awareness, propensity score matching

Introduction

Global environmental problems are becoming increasingly prominent, and are affecting people's lives and hindering economic and social development [1].

Governments attach great importance to the issue of environmental pollution, most of which is essentially caused by human activities and behaviors. In 1992, the Rio Declaration issued by the United Nations pointed out that public participation is vital for improving environmental pollution [2]. China is one of the countries with rapid economic development but severe air pollution. According to "Report on the State of the Ecology and Environment in China 2020" [3] released

*e-mail: royyang@zstu.edu.cn

by the Ministry of Ecology and Environment, 43.3% of China's cities at and above the prefecture level failed to meet national air quality standards.

Serious environmental problems are difficulties affecting the high-quality development of China's economy. The Chinese government has always attached great importance to ecological crises. The report of the 19th National Congress of the Communist Party of China pointed to "constructing a modern environmental governance system led by the government, with the participation of business entities and the public". Environmental protection requires not only the participation of the government and enterprises but also the participation of residents. According to international practical experience, encouraging residents' environmental protection behavior is an essential measure to promote ecological system reform and improve ecological degradation [4]. Therefore, research on the factors affecting individuals' pro-environmental behavior is also helpful to provide more practical advice for solving environmental problems.

Meanwhile, the rapid development of the Internet is reshaping real life and influencing residents' attitudes and behavior [5-6]. As of June 2021, the Chinese Internet penetration rate reached 71.6% [7]. Internet technology not only positively promotes China's macroeconomy but also has a profound impact on the lives and work of residents [8-9]. The Internet provides a platform for public welfare environmental activities, which plays a vital role in the cause of environmental protection [10-12]. For example, Ant Forest (an Alipay app) users can obtain green energy from low-carbon deeds. Therefore, users can exchange real trees through these green energies; thus, Ant Forest and nonprofit institutions plant these trees in sandy areas. From 2016 to 2020, more than 220 million trees were planted across more than 2,000 km² of planting area, realizing a cumulative reduction of more than 12 million tons of carbon emissions [13]. Internet technology realizes the in-depth integration of virtual reality [4] and increases public participation in carbon emission reduction activities. As a new medium, the Internet plays a vital role in social mobilization and public opinion about ecological protection through communication science [14]. Therefore, it is necessary to study the effect of Internet access on residents' PEB. However, more scholars focus on the relationship between Internet access and attitudes toward environmental protection [15-16]; although some studies are concerned about the relationship between Internet access and PEB [17-19]. The literature does not consider the endogeneity problem [18], as it is not handled well [17, 19]. There is still a lack of literature that explores the mediating role of environmental awareness.

This paper uses propensity score matching (PSM) to empirically analyze the effect of Internet access on residents' PEB, which comprises private-sphere pro-environmental behavior and public-sphere pro-environmental behavior. The possible marginal

contributions of this paper are as follows. First, this paper objectively divides pro-environmental behavior into private-sphere PEB and public-sphere PEB and examines the impact of Internet access on them. Thus, the research on residents' PEB is more specific. This paper further considers the heterogeneous impact of Internet access on residents' PEB. It analyzes the heterogeneous impact from the four aspects of residents' age, gender, education level, and residential location. Second, this paper selects the e-commerce development index at the provincial level as an instrumental variable and uses two-stage least squares (2SLS) regression to address the endogeneity problem. The instrumental variable of this paper is different from existing pieces of literature [17, 19], that is, the e-commerce development index at the province level. Therefore, the reliability of the research conclusions was verified. Third, this paper finds that environmental awareness has a mediating effect on the relationship between Internet access and PEB. This paper focuses on Internet access and theoretically analyzes the environmental protection effect of the Internet. It provides a micro reference basis for understanding the positive role of internet technology in residents' PEB and has strong practical significance for research on pro-environmental behavior. Thus, in the context of global environmental problems, some policy suggestions for developing countries' pro-environmental behavior can be drawn based on the conclusions of this study.

The rest of this paper is structured as follows. The second section conducts a literature review and proposes hypotheses. The third section introduces data sources, empirical strategy, and variable selection. The fourth section reports the main empirical findings on the impact of Internet access on residents' pro-environmental behavior. The fifth section provides an endogeneity discussion and robustness test. The sixth section examines the mediating effect of environmental awareness. The seventh section summarizes the main conclusions, puts forward corresponding policy recommendations, and directions for future research.

Literature Review and Hypothesis

Research on environmental protection has been a long-term concern for scholars. Governments and scholars of various countries have strengthened investment and scientific research in environmental protection, especially as ecological problems such as global warming and harsh climate emerge one after the other. The existing literature analyzes environmental protection issues from the government, enterprise, and individual perspectives. Some studies have shown that environmental policies have played a significant role in promoting environmental protection and governance [20-22]. Environmental management at the corporate level can effectively control enterprise environmental pollution [23-25]. The existing literature focuses

more on the effect of personal characteristics and environmental attitudes on personal pro-environmental behavior [26-29].

Scholars are trying to find other factors that affect personal environmental awareness and behavior based on the existing literature. The role of the media in environmental protection is now gradually being considered by the academic community. The media is divided into traditional media (television and newspaper) and new media (Internet) from the perspective of communication science. These media outlets have the role of disseminating environmental information [30] and are also the primary way for the public to obtain environmental information [14]. Some studies have suggested that mass media significantly promotes individual pro-environmental behavior [30-31]. Among them, traditional media can enable personal environmental awareness [32], willingness [33], and behavior [30, 34].

In a contemporary society, the Internet is a vital path for promoting environmental protection. Internet technology can improve production efficiency and energy utilization [35-36] and encourage green growth [37], which is conducive to reducing environmental pollution [38]. At the microlevel, the Internet as a new media not only has all the functions of traditional media but also the characteristics of a wide range of information dissemination, instant information dissemination, and breakthroughs in space limitations [39]. Residents can obtain a large amount of environmental information in a timely and effective way through the Internet [40]. Environmental information enhances the risk perception of residents [15, 41] and further affects their environmental satisfaction and quality evaluation [15, 42]. The above studies not only examine the impact of environmental protection policies at the macrolevel but also confirm the positive effect of the mass media on environmental protection.

Human behavior choices subtly change under the influence of the functions of the Internet, such as real-time communication, resource sharing, and spatiotemporal stagger [43]. Scholars in the field of mass media research usually regard media as the leading force for information dissemination and social mobilization [14, 44], which can affect residents' environmental awareness [32] and thus affect environmental behavior [17-19, 30]. The Internet has completely subverted the characteristic that traditional media can only transmit information in one direction. Netizens can publish information through the Internet anytime and anywhere. The Internet can break the time and space limitations of conventional information dissemination and broaden the channels of information dissemination [18]. Netizens can quickly and conveniently obtain much environmental information through the Internet [30, 45]. Public issues caused by environmental pollution, such as climate warming and haze, can induce emotional resonance and crisis awareness [15], because the information disseminated on the Internet

is relatively complex, with much negative information such as environmental pollution videos, texts, and data materials. The negative bias theory emphasizes that negative news attracts more people's attention [46]. Therefore, information about environmental pollution (pictures and videos, etc.) is more likely to stimulate netizens, causing emotional resonance such as crisis, tension, and anxiety [47]. Information on environmental pollution can help netizens judge environmental pollution and urge them to raise awareness for survival [48], thereby increasing their attention to environmental protection. According to the theory of evolution, when people face survival problems, they consciously change their lives and behaviors to face possible crises. Thus, to survive in a safe environment, netizens will actively adjust their attitudes toward environmental protection and then participate in eco-environmental protection activities.

The Internet can also improve the information transparency of the environmental protection behavior of the government and enterprises [49-50]. The government, enterprises and netizens can all participate in environmental supervision [51]. Therefore, Internet platforms can effectively promote environmental protection. For example, "clear water and green mountains are as valuable as mountains of gold and silver;" "garbage classification," and other information can have a positive effect on netizens' environmental attitudes, further improving the importance of environmental protection for netizens. At the same time, environmental information affects netizens' environmental protection behavior [52]. Some scholars argue that mass media can promote pro-environmental behavior [17-18, 30]. According to the existing literature, pro-environmental behaviors are usually divided into private-sphere and public-sphere pro-environmental behaviors [53]. Public-sphere pro-environmental behavior usually refers to behaviors such as participating in environmental protection donations, while private-sphere pro-environmental behavior usually refers to garbage classification [54].

Based on the above analysis, this paper divides residents' environmental behavior into public-sphere and private-sphere environmental behavior and proposes the following hypotheses:

H1 Internet access has a significant positive impact on residents' private-sphere and public-sphere pro-environmental behavior.

"Awareness-behavior" theory is the primary economic paradigm that explains individual behavioral choices. Therefore, environmental awareness is the main influencing factor of individual pro-environmental behavior [55], indicating the individual's understanding of environmental conditions, environmental pollution issues, and environmental protection policies [56]. If individuals have low or even no knowledge of environmental protection, they will not have the understanding for judging ecological risks [57]. Therefore, their willingness will be weakened, affecting

individual pro-environmental behavior [58]. Meanwhile, as the main channel through which individuals obtain environmental information, the Internet builds a dissemination platform for environmental knowledge, which helps individuals understand environmental issues. Their environmental awareness and changing environmental attitudes will be improved [17-19, 59]. Thus, the Internet encourages individuals to consciously adopt pro-environmental behavior.

When assessing environmental issues, ordinary residents lack environmental expertise. The Internet can provide them with much environmental knowledge. Therefore, the internet improves the environmental knowledge system and helps supplement the reserve of environmental expertise [60]. Residents' environmental awareness is further improved [17-19, 61], thereby promoting residents' pro-environmental behaviors. On the other hand, the Internet also built a discussion platform for residents on environmental protection activities. Residents can participate in environmental issues and exchange ideas through the Internet. According to the theory of collective action, the Internet not only provides a platform for spreading environmental protection news but also provides a communication space for environmental protection activists to build a collective identity for environmental protection [62]. They then form collective environmental awareness. Thus, the Internet plays a vital role in promoting environmental awareness. This paper proposes the following hypotheses:

H2 Environmental awareness plays a mediating role between Internet access and residents' private-sphere and public-sphere pro-environmental behavior.

Materials and Methods

Data Sources and Research Sample

This paper focuses on the impact of Internet access on residents' PEB. By comparing open microdata, only the Chinese General Social Survey 2013 data (CGSS2013) [63] contain detailed information about individual Internet access, environmental awareness, and pro-environmental behavior. For example, some scholars use CGSS2013 to study environmental quality assessment [15, 42] and environmental behavior [17-19]. Although these data are not the most up-to-date data, they can still reflect the real relationship between Internet access and residents' PEB. Therefore, this paper uses the data from the CGSS2013. In recent years, China has experienced rapid development of ICT and is more focused on environmental pollution. It is necessary to analyze the relationship between Internet access and residents' PEB. The research conclusions of this paper may provide practical environmental protection suggestions for developing countries. The Department of Sociology of the Renmin University of China and the Survey Research Center of Hong

Kong University of Science and Technology jointly launched the CGSS in 2013. This survey covered rural and urban areas in 28 provinces, municipalities, and autonomous regions in China, with a sample size of 11,438. The respondents were between the ages of 18 and 95. According to the needs of empirical research, the required variables are retained, and the samples with missing, inapplicable, and unknown values are deleted. Finally, 10993 valid samples are obtained, covering 28 provinces, municipalities, and autonomous regions across rural and urban areas in China.

Empirical Strategy

The PSM method with STATA16 was used to estimate the effect of Internet access on residents' PEB. Previous studies use the ordinary least squares (OLS) method for empirical analysis [17-19]. However, the PSM method is the best approach to correct the selection bias compared with the OLS method [64]. According to Rosenbaum and Rubin [65], the PSM method obtains unbiased effects on the outcome variables. Therefore, this study uses PSM to estimate the causal effects of Internet access on residents' PEB. The basic idea of PSM is based on counterfactual inference [65]. PSM finds counterfactual control groups (non netizens) similar to the treatment group (netizens) by matching. This study focuses on the average treatment effect on the treated (ATT) of Internet access as follows:

$$ATT = E(PEB_1 | IA = 1) - E(PEB_0 | IA = 1) = E(PEB_1 - PEB_0 | IA = 1) \quad (1)$$

where *PEB* is pro-environmental behavior, *IA* is Internet access, and $E(PEB_1 | IA = 1)$ refers to respondents' pro-environmental behavior when using the Internet. $E(PEB_0 | IA = 1)$ refers to the counterfactual result that is not directly observable and represents the netizens' PEB when they are not using the Internet. The counterfactual result is that the most similar individuals of netizens can be matched with non netizens based on the selected covariates. Therefore, the average counterfactual difference in PEB between netizens and matched non netizens can be measured, which is the net effect of Internet access on PEB. The specific steps of PSM are as follows. Previous studies use OLS for empirical analysis [17-19]. In comparison, PSM is more effective than OLS.

First, under the condition of given covariates, the propensity score is estimated by constructing the logit model or probit model. The affecting residents' Internet access of covariates includes individual characteristic variables, social attitude characteristic variables, family characteristic variables, household registration variables, residential location variables, and province variables. Second, matching results need to pass the data balancing test. Third, this paper uses matching methods to match and pair the treatment group with the control group, which includes kernel matching

(bandwidth = 0.1), radius matching (caliper = 0.05) [66], and k-nearest neighbor matching (k = 4) [67]. Finally, measuring ATT of Internet access on PEB.

To measure the mediating effect of environmental awareness (*EA*) on the relationship between Internet access (*IA*) and pro-environmental behavior (*PEB*), the mediating test was applied through the bootstrap mediating test method (based on the PROCESS of SPSS26). The equations are set as follows.

$$PEB = i_1 + cIU + e_1 \quad (2)$$

$$EA = i_2 + aIU + e_2 \quad (3)$$

$$PEB = i_3 + c'IU + bEA + e_3 \quad (4)$$

where *EA* is environmental awareness and *c* is the estimated coefficient of *IA* on residents' PEB. *a* is the estimated coefficient of *IA* on residents' *EA*. *c'* and *b* are the estimated coefficients of *IA* and residents' *EA* on *PEB*, respectively. *EA* of Equation (4) is the mediating factor. According to Preach and Hayes [68], the indirect effect of *IA* on *PEB* in this model is defined as the product of the *IA*→*EA* path (*a*) and the *EA*→*PEB* path (*b*), or *ab*. If *ab* is significant and zero and is not in the 95% confidence interval, the results indicate that *IA* affects residents' PEB through *EA*. On this basis, if *c'* is nonsignificant, *EA* plays a full mediating effect; if *c'* is significant, *EA* plays a part in the mediating effect. It should also be noted that a significance test associated with *ab* should address mediation more directly than a series of separate significance tests not directly involving *ab* [68].

Measures

Residents' pro-environmental behavior (PEB) is the dependent variable of this paper, and its meaning refers to any behavior conducive to environmental protection [69]. CGSS2013 asked respondents whether they had engaged in any of the following activities or behaviors in the past year, specifically including 10 questions about residents' PEB. According to Wang et al. [70], residents' pro-environmental behavior is divided into private-sphere and public-sphere. There are five items about private-sphere pro-environmental behavior (Pr-PEB) that include "garbage sorting"; "discussing environmental issues with friends"; "bringing a bag when purchasing daily necessities"; "reusing plastic bags"; and "paying attention to media coverage on environmental issues". The other five items about public-sphere pro-environmental behavior (Pu-PEB) include "donating for environmental protection", "actively participating in environmental publicity activities for the government", "actively participating in environmental activities for nongovernmental environmental groups", "maintaining the woods or green spaces at your own

expense", and "actively participating in complaints and appeals on environmental issues" (1 = never, 2 = occasionally, and 3 = frequently). SPSS26 is used to test for sufficient reliability. The Cronbach's alpha coefficients are 0.668 and 0.760, indicating outstanding internal consistency. Therefore, this study constructed the index of private-sphere PEB and public-sphere PEB based on the average score of each resident in the above items. They are continuous variables, ranging from 1 to 3, and the higher the score is, the higher the degree of residents' pro-environmental behavior.

Internet access (*IA*) is the independent variable of this paper. CGSS2013 asked respondents about their usage of computer Internet and mobile Internet in the past year (1 = never, 2 = little, 3 = sometimes, 4 = frequently, 5 = always). This study reclassifies the five categorical variables into two categorical variables (0 = never, the other options = 1). The option of the never refers to the non netizens, and the other options refer to the netizens.

Environmental awareness (*EA*) is the mediating variable in this study, and its meaning refers to the degree of understanding of environmental protection. Previous studies only use one question in CGSS2013 to measure environmental awareness variable [19]. This paper use ten questions to measure environmental awareness variable. The CGSS2013 asked respondents about mastery of knowledge about environmental protection, specifically responding to 10 questions on environmental awareness. For example, "automobile exhaust, excessive use of fertilizers and pesticides, detergent containing phosphate, acid rain, and refrigerators containing fluorine, those problems which pose a threat to human health and cause environmental damage, and so on". *EA* is defined as the correct score for examining these questions (0 = wrong or I don't know, 1 = correct), and finally, the average to obtain a continuous variable of 0 to 1. The higher the score is, the higher the residents' *EA*.

According to Zhang et al. [15] and Gong et al. [17], individual characteristic variables, social attitude characteristic variables, family characteristic variables, household registration variables, residential location variables, and province variables are selected as control variables in this paper. The descriptive statistics of each variable are shown in Table 1. The definitions of the control variables are shown in Table A1 (see Appendix A).

Results and Discussion

Descriptive Statistical Analysis of the Respondent

Table 1 showed that 43.5% were netizens. Netizens have a higher degree than private-sphere PEB and public-sphere PEB with non netizens (1.998>1.727, 1.281>1.121). The results preliminarily indicate

Table 1. The statistical description of grouped sample variables.

Variable symbol	Complete sample		Netizens (IA = 1)		Non netizens (IA = 0)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Pr-PEB	1.845	0.471	1.998	0.452	1.727	0.452
Pu-PEB	1.191	0.324	1.281	0.374	1.121	0.260
IA	0.435	0.496	1	—	0	—
EA	0.4712	0.2860	0.6142	0.2517	0.3611	0.2610
Gender	0.505	0.500	0.535	0.499	0.481	0.500
Age	48.495	16.384	37.430	12.817	57.018	13.482
Age ²	2620.216	1652.467	1565.298	1088.876	3432.724	1550.308
Edu	3.042	1.258	3.911	0.978	2.372	1.016
Identity	0.102	0.302	0.136	0.342	0.076	0.264
Marriage	0.897	0.305	0.784	0.411	0.983	0.130
Health	3.715	1.081	4.117	0.854	3.405	1.134
Religion	0.112	0.316	0.099	0.299	0.122	0.327
Trust	3.280	1.032	3.182	1.025	3.355	1.028
Happiness	3.758	0.838	3.816	0.773	3.713	0.882
FE	2.687	0.680	2.844	0.627	2.566	0.694
HP	3.090	1.414	3.186	1.286	3.016	1.500
Register	0.448	0.497	0.604	0.489	0.604	0.489
Residence	1.895	0.929	1.516	0.801	1.517	0.801
Province	1.849	0.794	1.658	0.777	1.995	0.775
N	10993		4783		6210	

a positive relationship between IA and residents' PEB. The paper will empirically test the impact of IA on residents' PEB. The respondents were mostly male (50.5%), the average age of respondents was 48, and the average age of netizens was significantly smaller than that of non netizens (37<57). Most respondents were junior high school or below (64.4%), married (89.7%), healthy or above (64.3%), and happy or above (72.4%).

Internet Access and Pro-Environmental Behavior

This section uses PSM to analyze the impact of Internet access on residents' pro-environmental behavior. Table 2 provides the estimated results of IA on residents' private-sphere PEB and public-sphere PEB. The results include the ATT of unmatched, kernel matching, k-nearest neighbor matching, and radius matching. As shown in Table 4, the ATT of the three matching methods is basically similar, indicating that the estimated result is robust. Meanwhile, this paper uses ordinary least squares (OLS) to verify the main regression result, which is also robust (see Appendix B, $\beta = 0.0744$, $p < 0.01$).

This study mainly reports the estimation results of kernel matching. Regarding private-sphere PEB, the ATT of the unmatched is estimated to be 0.2709, which is statistically significant ($t = 31.17$, $p < 0.01$). However, the ATT of the kernel matching is estimated to be 0.0983, which is statistically significant ($t = 3.51$, $p < 0.01$). Regarding public-sphere PEB, the ATT of the unmatched is estimated to be 0.1597, which is statistically significant ($t = 26.39$, $p < 0.01$). However, the ATT of the kernel matching is estimated to be 0.1127, which is statistically significant ($t = 6.72$, $p < 0.01$). In summary, the empirical results show that IA has a significant positive effect on residents' private-sphere PEB and public-sphere PEB, indicating that IA can promote the degree of residents' PEB. By further comparing the ATT of private-sphere PEB and public-sphere PEB, IA has a higher promotion effect on public-sphere PEB. Therefore, the above conclusions verify Hypothesis H1.

On the one hand, residents can access much environmental information through the Internet, which helps residents understand the harm caused by environmental pollution to the air and water that humans depend on for survival. According to the

Table 2. Results of the PSM and hypothesis testing.

Dependent variable	Sample	Treated (Netizens)	Controls (Non netizens)	ATT	S.E.	t-value
Pr-PEB	Unmatched	1.9976	1.7267	0.2709	0.0087	31.17***
	Kernel matching	1.9973	1.8990	0.0983	0.0280	3.51***
	K-nearest neighbor	1.9973	1.8938	0.1034	0.0420	2.46**
	Radius matching	1.9973	1.8925	0.1042	0.0323	3.24***
Pu-PEB	Unmatched	1.2812	1.1215	0.1597	0.0061	26.39***
	Kernel matching	1.2776	1.1650	0.1127	0.0168	6.72***
	K-nearest neighbor	1.2776	1.1674	0.1102	0.0267	4.13***
	Radius matching	1.2776	1.1590	0.1187	0.0192	6.72***

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

negative bias theory [46], netizens are more likely to be stimulated by negative news, so they are more inclined to pay attention to food safety and physical and mental health. These factors further promote residents' environmental protection activities. Internet platforms have an advertising effect that can break through traditional publicity methods and quickly and conveniently disseminate ecological environmental protection propaganda or videos. Thus, Internet access is conducive to cultivating residents' sense of environmental protection responsibility and motivating residents to participate in public activities of public-sphere environmental protection. These factors increase the degree of residents' pro-environmental behavior.

Probabilistic Model Selection and Balance Test

Before conducting PSM, we need to obtain propensity scores. The results of the propensity score are presented in Table B1 (see Appendix B). We adjusted R^2 and AUC to determine the best matching model. As Table B1 shows, the AUCs of the two models are the same. However, the adjusted R^2 of the logit model is greater than the adjusted R^2 of the probit model (0.5215 > 0.5179), which indicates that the logit model is more accurate than the probit model. Therefore, this study uses the logit model to obtain propensity scores.

To ensure the reliability of matching, it is necessary to balance the test of the matching results. Table B2 shows the balance test results (See Appendix B). The pseudo R^2 value of the unmatched sample is 0.518; after the three matching methods are matched, the pseudo R^2 value drops to 0.035~0.042. The LR chi2 value dropped from unmatched (7796.04) to matched (455.10~546.53). The standard bias of matching is also significantly reduced. In summary, PSM can reduce the difference in explanatory variables between the treatment group (netizens) and the control group (non netizens). The balance test result indicates that the PSM of this

study has a well-balanced matching and can obtain reliable estimation effects.

Heterogeneity Analysis

Differences in personal characteristics will also affect residents' pro-environmental behavior. Studies have shown that women are more environmentally friendly than men and respond more positively to environmental issues [71]. Residents' age, education level, and residential location also determine differences in environmental attitudes and awareness [15, 26, 71], which leads to the heterogeneous effects of the Internet access on residents' PEB. Therefore, this paper further discusses subdivided groups based on residents' age, gender, education level, and residential location. The heterogeneity results are obtained from the kernel matching of PSM.

Age

As shown in Table 3, regarding age, this study divides the age of the respondents into young, middle-aged, and old residents. Regarding private-sphere PEB, IA has a significant positive effect on private-sphere PEB for young (ATT = 0.1065, $t = 2.96$, $p < 0.01$) and old (ATT = 0.1336, $t = 4.15$, $p < 0.01$) residents, but ATT is greater in old residents; regarding public-sphere PEB, IU has a significant positive impact on residents' public-sphere PEB for both young (ATT = 0.0914, $t = 4.03$, $p < 0.01$), middle-age (ATT = 0.0939, $t = 5.46$, $p < 0.01$) and old (ATT = 0.0793, $t = 3.35$, $p < 0.01$) residents, but ATT is greater in middle-age residents. When old residents shop, they pay attention to reusing plastic bags and bring their shopping bags and other environmental protection-related lifestyle habits. Especially when old residents access the Internet to obtain environmental protection information, it is more conducive to understanding how to conduct garbage analysis and other environmental protection information. Therefore,

Internet access has a greater role in promoting private-sphere PEB among old residents. On the other hand, young and middle-aged residents are more adept on the Internet. Therefore, the online complaints of environmental issues and online registration of public-sphere environmental protection activities are more familiar. Young and middle-aged residents' physical health is better than that of old residents. They are more active in environmental protection activities such as environmental publicity and education, tree planting, and forest protection. Therefore, the promotion effect of Internet access is relatively large on the public-sphere PEB of young and middle-aged residents.

Gender

As shown in Table 3, regarding gender, IA has a significant positive effect on residents' private-sphere PEB and public-sphere PEB for both males and females. Nevertheless, the ATT of female residents was greater for both private PEB (ATT = 0.1063, $t = 2.77$, $p < 0.01$) and public-sphere PEB (ATT = 0.1103, $t = 4.95$, $p < 0.01$). Studies also show that female residents focus more on environmental issues than male residents, and they are more inclined to adopt PEB [71]. The reason for is the division of labor mode of men dominating in outside activities and women dominating in inside activities in traditional Chinese culture [26]. Therefore, female residents are better than male residents on private-sphere PEB. On the other hand, female residents have a

more sensitive and positive attitude than male residents toward problems. Therefore, female residents access information on public-sphere environmental activities through the Internet which encourages female residents to participate in activities such as environmental protection donations and environmental appeals.

Education Levels

As shown in Table 3, regarding education levels (Edu), this study divides the education levels of the respondents into primary school or below, junior high school, and senior high school or above. Regarding private-sphere PEB, IA has a significant positive effect on private-sphere PEB for junior high school or below. Regarding public-sphere PEB, IA significantly promotes residents' public-sphere PEB for all education levels, but the effect is greater on senior high school or above (ATT = 0.224, $t = 3.46$, $p < 0.01$). The above results reflect that less-educated residents use the Internet to obtain information on private-sphere PEB, such as garbage classification. In contrast, highly educated residents can use their knowledge to better participate in private-sphere PEB, so there is no need to access private-sphere PEB information through the Internet. Public-sphere environmental protection activities can be effectively disseminated on the Internet platform; hence, residents with a high level of education tend to have a better social status, are more concerned about public issues, and are more active in joining environmental activities

Table 3. The results of subdivided sample analysis.

Heterogeneity variable	Group standard	Pr-PEB		Pu-PEB	
		Kernel matching		Kernel matching	
		ATT	t-value	ATT	t-value
Age	Young	0.1065 (0.0360)	2.96***	0.0914 (0.0227)	4.03***
	Middle-age	0.0283 (0.0243)	1.17	0.0939 (0.0172)	5.46***
	Old	0.1336 (0.0322)	4.15***	0.0793 (0.0237)	3.35***
Gender	Male	0.0926 (0.0416)	2.29**	0.1096 (0.0258)	4.25***
	Female	0.1063 (0.0388)	2.77***	0.1103 (0.0223)	4.95***
Edu	Primary school or below	0.0692 (0.0282)	2.45**	0.0766 (0.1097)	3.89***
	Junior high school	0.0881 (0.0264)	3.33***	0.0495 (0.0166)	2.97***
	Senior high school or above	0.0614 (0.0488)	1.26	0.1224 (0.0354)	3.46***
Residence	Urban	0.0918 (0.0372)	2.47**	0.1128 (0.0251)	4.49***
	Rural	0.1005 (0.0281)	3.57***	0.0770 (0.0171)	4.51***

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Numbers in parenthesis are standard error.

in the public-sphere through the Internet [17], so the ATT of high school and above is greater.

Residential Location

As shown in Table 3, regarding residential location (residence), this study divides the residential location of the respondents into urban and rural. IA significantly promotes residents' PEB for urban and rural areas. Among them, regarding private-sphere PEB, the ATT of rural residents (ATT = 0.1005, $t = 3.57$, $p < 0.01$) is greater; regarding public-sphere PEB, the ATT of urban residents (ATT = 0.1128, $t = 4.49$, $p < 0.01$) is greater. The government promotes the construction of an ecological civilization that is necessary to start with rural residents' private-sphere PEB. The government uses the Internet platform to vigorously promote the importance of environmental protection behaviors such as rural waste classification. The environmental protection knowledge on the Internet, such as understanding the harm caused by environmental damage, is more helpful for rural residents. This promotes the importance of rural residents on PEB. In addition, urban residents have more awareness of rights protection than rural residents. Under the digital supervision service model, urban residents access the Internet to actively participate in online environmental complaints and online donations. Therefore, Internet access has a greater effect on urban residents' public-sphere PEB.

Discussion of Endogeneity

The above estimation results show that IA significantly promotes residents' private-sphere PEB and public-sphere PEB. However, endogeneity problems

may exist in the model. The low degree of pro-environmental behavior leading to residents obtaining environmental information through the Internet maybe the reason for this. If these residents want to understand more about environmental protection knowledge and environmental protection laws, then they would use the Internet to access such knowledge. Therefore, the possible endogeneity problems of the benchmark model can be solved by the instrumental variable method. The instrumental variable selected in this study is the e-commerce development index at the provincial level in 2013 (EDI). The EDI is calculated by AliResearch, which was published in the "2013 China Urban E-commerce Development Index Report". The EDI is composed of an online business index and an online shopping index. E-commerce can not only drive economic growth but also promote residents' Internet access. The EDI for a province is higher; hence, more people will be encouraged to use the Internet, which generates a peer effect so that residents are more likely to access the Internet. However, the EDI cannot directly affect residents' PEB. Therefore, this paper selects the EDI as an instrumental variable and uses 2SLS regression for empirical analysis.

Model (1) in Table 4 is the estimation result of EDI on IU. The results show that EDI significantly promotes IA ($\beta = 0.0042$, $p < 0.01$), indicating a strong correlation between EDI and IA. The Kleibergen-Paap rk LM statistic is 35.150 ($p < 0.01$), indicating that the underidentification test can strongly reject the null hypothesis. The CD Wald F statistic and KP rk Wald F statistic are 37.437 ($p < 0.01$) and 35.355 ($p < 0.01$), respectively, indicating that weak instruments can strongly reject the null hypothesis. The Hausman test ($p < 0.01$) and DWH test ($p < 0.01$) reveal that IA is an endogenous variable. Based on the above test,

Table 4. Discussion of endogeneity: the instrumental variables method.

Variable	First stage	Second stage	
	(1) IA	(2) Pr-PEB	(3) Pu-PEB
IA		2.6054*** (0.4686)	1.5567*** (0.2971)
EDI	0.0042*** (0.0007)		
Control variables	YES	YES	YES
Kleibergen-Paap rk LM	35.150***		
Cragg-Donald Wald F	37.437***		
Kleibergen-Paap rk Wald F	35.355***		
Hausman test		157.75***	100.64***
Durbin-Wu-Hausman test		160.03***	101.56***
N	10993	10993	10993

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Numbers in parenthesis are robust standard error.

the instrumental variable meets the conditions, indicating that the estimated results are valid. Model (2) and Model (3) in Table 4 show the effect of IA on private-sphere PEB and public-sphere PEB. The results show that IA still significantly promotes residents' private-sphere PEB ($\beta = 2.6054, p < 0.01$) and public-sphere PEB ($\beta = 1.5567, p < 0.01$) after considering endogeneity problems. These results further confirm the robustness of the benchmark regression.

Robustness Test

This study verifies the robustness of the benchmark model from three aspects. First, the principal component factor analysis method is used to remeasure the dependent variable. Two common factors that include the common factor of private-sphere PEB (Fa-Pr-PEB) and the common factor of public-sphere PEB (Fa-Pu-PEB) are obtained. The Kaiser–Meyer–Olkin (KMO) with SPSS26 is used for sufficient test. The KMO value is 0.811, and the factor loadings of each index are greater than 0.5 after using the maximum variance method to rotate, indicating that the effect of dimension reduction is better. After conducting kernel matching of PSM, the ATT of the remeasuring dependent variable is shown in Table 5. The results show that IA has a significant positive impact on residents' Fa-Pr-PEB (ATT = 0.1458, $t = 2.06, p < 0.05$) and Fa-Pu-PEB (ATT = 0.3534, $t = 5.80, p < 0.01$). Second, the core independent variable is replaced with "surfing the Internet in free time". Due to residents accessing the Internet in their free time to obtain information, "surfing the Internet in free time" will also have an impact on environmental behavior. Therefore, this study uses "surfing the Internet in free

time" to replace the benchmark model with Internet access. As shown in Table 5, surfing the Internet in free time significantly promotes residents' private-sphere PEB (ATT = 0.0800, $t = 3.10, p < 0.01$) and public-sphere PEB (ATT = 0.0745, $t = 4.77, p < 0.01$). Third, the PSM is replaced with coarsened exact matching (CEM). The estimation results of the CEM method are shown in Table 5. IA significantly promotes residents' private-sphere PEB (ATT = 0.1007, $t = 2.56, p < 0.05$) and public-sphere PEB (ATT = 0.0554, $t = 2.09, p < 0.05$). Based on the analysis of the above three robustness test methods, the results further reveal that IA can significantly promote residents' PEB and confirm the robustness of the results.

The Mediating Test of Environmental Awareness

Previous empirical results have shown that IA significantly promotes residents' private-sphere PEB and public-sphere PEB. This part focuses on the mechanism by which IA affects residents' PEB. The above theoretical analysis shows that the information effect of the Internet will further promote the dissemination of environmental knowledge among residents, thereby improving residents' environmental awareness and promoting residents' environmental protection behaviors. As shown in Table 6, the results of the estimated coefficients (a, b, c') show that IA significantly promotes EA ($a = 0.2530, p < 0.01$), and IA and EA both have a significant positive impact on private-sphere PEB ($b = 0.5506$ and $0.1708, p < 0.01$) and public-sphere PEB ($c' = 0.1316$ and $0.1165, p < 0.01$). The mediating effect of IA on PEB in this situation is

Table 5. The results of the robustness test.

Test methods	Dependent variable	Sample	Treated (Netizen)	Controls (Non netizen)	ATT	S.E.	t-value
Remeasure dependent variable	Fa-Pr-PEB	Unmatched	0.2614	-0.2014	0.4628	0.0187	27.71***
		Kernel matching	0.2625	0.1167	0.1458	0.0708	2.06**
	Fa-Pu-PEB	Unmatched	0.2738	-0.2109	0.4848	0.0187	25.96***
		Kernel matching	0.2632	-0.0902	0.3534	0.0610	5.80***
Replace core independent variables	Pr-PEB	Unmatched	2.0068	1.7287	0.2781	0.0087	31.88***
		Kernel matching	2.0067	1.9267	0.0800	0.0258	3.10***
	Pu-PEB	Unmatched	1.2840	1.1245	0.1594	0.0061	26.19***
		Kernel matching	1.2833	1.2089	0.0745	0.0156	4.77***
Replace measurement model	Pr-PEB	Unmatched	1.9976	1.7267	0.2709	0.0087	31.17***
		Kernel matching	1.9782	1.8775	0.1007	0.0393	2.56**
	Pu-PEB	Unmatched	1.2812	1.1215	0.1597	0.0061	26.39***
		Kernel matching	1.2168	1.2114	0.0554	0.0266	2.09**

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6. The mediating test of environmental awareness.

Mediating test	Pr-PEB	Pu-PEB
<i>a</i>	0.2530*** (0.0049)	0.2530*** (0.0049)
<i>b</i>	0.5506*** (0.0159)	0.1708*** (0.0116)
Mediating effect (<i>ab</i>)	0.1393*** (0.0049)	0.0432*** (0.0032)
Mediating confidence interval	BootLLCI = 0.1297 BootULCI = 0.1491	BootLLCI = 0.0368 BootULCI = 0.0493
Direct effect (<i>c'</i>)	0.1316*** (0.0092)	0.1165*** (0.0067)
Direct confidence interval	LLCI = 0.1136 ULCI = 0.1496	LLCI = 0.1034 ULCI = 0.1295
Total effect (<i>c</i>)	0.2709*** (0.0087)	0.1597*** (0.0061)
Mediating effect/Total effect	51.42%	27.05%
Test results	Establish	Establish

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; Numbers in parenthesis are standard error. 5000 bootstrap samples. 95% level of confidence.

defined as the product of IA→EA path *a* and EA→PEB path *b*, or *ab*. Regarding private-sphere PEB, the mediating effect of EA is estimated to lie between 0.1297 and 0.1491 with 95% confidence (zero not in the confidence interval, $ab = 0.1393$, $p < 0.01$), accounting for 51.42% of the total effect, indicating that EA plays a part in the mediating role in the path of IA to promote residents' private-sphere PEB. Regarding public-sphere PEB, the mediating effect of EA is estimated to lie between 0.0368 and 0.0493 with 95% confidence (zero not in the confidence interval, $ab = 0.0432$, $p < 0.01$), accounting for 27.05% of the total effect, indicating that EA plays a part in the mediating role in the path of IA to promote residents' public-sphere PEB. In summary, whether private-sphere PEB or public-sphere PEB, EA is an essential mechanism by which IA promotes residents' PEB. Therefore, the above conclusions verify Hypothesis H2.

Conclusions, Recommendations and Future Research

This paper starts from the perspective of Internet access, based on the theoretical analysis of PEB in communication and environmental economics, and points out that Internet access improves environmental awareness, thereby promoting PEB. Based on CGSS2013 data, this paper uses the PSM method to empirically analyze the effect of Internet access on residents' PEB. According to previous studies, Internet technology can improve labor productivity [35] and encourage green growth [37], thereby reducing environmental pollution [38]. However, there is a lack of literature on environmental protection at the microlevel of Internet

technology. The empirical results of this study show that Internet access significantly promotes residents' PEB. Among them, the effect of public-sphere PEB is greater than that of private-sphere PEB. This study further verifies the conclusion of Xiao et al. (2022). However, comparing the regression coefficients of the two studies shows that the regression coefficients of this study are much smaller than that of Xiao et al. (2022). Because the distribution of netizens and non netizens is not completely random, this paper uses the PSM method can effectively solve the selection bias problem [64], further indicating that the findings of this paper are more realistic. In addition, unlike the study by previous studies [17-19], this study finds that Internet access has a greater effect on private-sphere PEB for elderly, women, low educated and rural residents. Internet access has a greater effect on public-sphere PEB for middle-aged, women, higher educated and urban residents. After addressing the possible endogeneity problems and conducting the robustness test from three aspects, Internet access still significantly promotes private-sphere PEB and public-sphere PEB. The results of the mediating test show that Internet access not only promotes residents' PEB but also promotes residents' PEB by enhancing their environmental awareness. This paper focuses on Internet access and expounds on the environmental effects of the Internet. It not only provides a micro reference basis for understanding the positive role of Internet technology in residents' PEB but also has vital practical significance for the study of PEB.

Based on the above research conclusions, to improve the ecological crisis in developing countries, this paper proposes the following policy recommendations from a micro perspective. The Internet is an important

medium to promote residents' pro-environmental behavior. Government departments should step up their efforts to promote environmental protection publicity on the Internet, using videos as the leading method and pictures and texts as the supporting method to carry out environmental protection publicity; including positive environmental protection news and environmental pollution news. Objective and fair reporting of issues can help stimulate residents' attention to environmental protection. Meanwhile, the government should improve the online complaint system for environmental issues. The government should also encourage Internet companies to consider the setting of environmental protection public welfare activities when developing software or small programs. At the same time, Internet companies should vigorously develop low-carbon living functions and applications, such as Ant Forests, Green Consumption and Shared Bicycles, thereby, training forests, green consumption and shared bicycles. Therefore, residents' awareness of green consumption and green travel should be trained. The government should help residents establish correct environmental values and guide residents to participate in environmental activities. The government should pay attention to individual differences in the environmental protection effect of the Internet. For residents of different ages, genders, education levels, and residential locations, the government or enterprise can divide pro-environmental behaviors into private-spheres and public-spheres for environmental protection publicity. The government should pay attention to the improving role of the Internet technology in environmental awareness when cultivating residents' pro-environmental behavior. On the one hand, the government and environmental protection companies can use Internet media to popularize environmental protection knowledge, such as the causes of climate warming, the factors that cause haze, and how to classify garbage. On the other hand, the Internet can conduct question-and-answer questions on environmental protection knowledge. Meanwhile, the Internet can carry out public welfare activities of environmental protection to mobilize residents' pro-environmental enthusiasm. This way it can influence private-sphere pro-environmental behaviors and promote public-sphere pro-environmental behaviors.

The limitations of this study and future improvement directions are as follows. First, due to availability of data, this paper only uses the 2013 national-level microdata. Therefore, the core variables are measured based on related questions of the existing data. Although the validity and reliability of the questionnaire have been tested, future studies may prepare to perfect the questionnaire and conduct follow-up surveys to form longitudinal data to test the research results further. Second, based on the existing questions in the questionnaire, this paper measures the variables of Internet access and forms a binary variable of yes or no. Therefore, it cannot observe the

purpose and the subjective feeling of residents using the Internet. Future research plans may build an indicator system of Internet access to analyze pro-environmental behavior from categories and experiences of Internet access. Finally, this study does not examine other specific mechanisms (such as environmental values and personal norms) of the relationship between Internet access and pro-environmental behavior. Therefore, improving the research conclusions of this study based on obtaining relevant data would be a direction for future improvement.

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Conflict of Interest

The authors declare no conflict of interest.

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Appendix

Appendix A

Table A1. Definition and measurement of control variables.

Control Variable	Code	Variable definition and type
Gender	Gender	Gender (1 = Male, 0 = Female)
Age	Age	Physical age (17~97, continuous variable)
Age ²	Age ²	Physical age squared (continuous variable)
Educational level	Edu	Current highest education level (1 = without education, 2 = primary school, 3 = junior high school, 4 = senior high school or technical secondary school, 5 = undergraduate or above)
Identity of Politics status	Identity	Politics status (1 = Communist Party of China, 0 = other parties)
Marital status	Marriage	Marital status (1 = married, 0 = unmarried)
Physical condition	Health	Physical condition (1 = very unhealthy, 2 = unhealthy, 3 = general, 4 = healthy, 5 = very healthy)
Religious beliefs	Religion	Whether respondents have religious beliefs (1 = Yes, 0 = No)
Society trust	Trust	Whether respondents agree that most people in society can be trusted (1 = very disagree, 2 = disagree, 3 = general, 4 = agree, 5 = very agree)
Happy level of life	Happiness	Whether respondents think your life is happy (1 = very unhappy, 2 = unhappy, 3 = general, 4 = happy, 5 = very happy)
Family economic status	FE	Family economic status (1 = well below average, 2 = below average, 3 = general, 4 = above average, 5 = well above average)
Household population	HP	Resident household population (1~12, continuous variable)
Registered permanent residence	Register	Registered permanent residence (1 = non-agricultural household registration, 0 = agricultural household registration)
Residential location	Residence	Residential location (1 = city, 2 = town, 3 = rural area)
Province	Province	Province (1 = eastern region, 2 = middle region, 3 = western regions)

Note: Eastern region includes Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Liaoning, Fujian, Shandong and Guangdong. Middle region includes Jilin, Heilongjiang, Shanxi, Anhui, Jiangxi, Hunan, Hubei and Hunan. Western region includes Neimenggu, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shanxi, Gansu, Qinghai and Ningxia.

Appendix B

Table B1. OLS, logit and probit estimation results.

Variables	(1) OLS	(2) Logit	(3) Probit
Control variables			
Gender	-0.0693*** (0.0118)	0.2013*** (0.0621)	0.1116*** (0.0349)
Age	0.0063*** (0.0083)	-0.2015*** (0.0153)	-0.1160*** (0.0082)
Age ²	-0.0000*** (0.0000)	0.0009*** (0.0002)	0.0006*** (0.0001)
Edu	0.0794*** (0.0049)	0.8726*** (0.0365)	0.4836*** (0.0198)
Identity	0.0673*** (0.0142)	0.2988*** (0.1036)	0.1593*** (0.0582)

Table B1. Continued.

Marriage	-0.0160 (0.0175)	-0.5425*** (0.1832)	-0.2391** (0.0977)
Health	0.0112*** (0.0043)	0.1100*** (0.0326)	0.0634*** (0.0182)
Religion	0.0067 (0.0128)	0.2314** (0.0967)	0.1200** (0.0536)
Trust	0.0154*** (0.0040)	-0.0222 (0.0293)	-0.0137 (0.0165)
Happiness	0.0213*** (0.0052)	0.0201 (0.0391)	0.0081 (0.0219)
FE	0.0032 (0.0064)	0.4288*** (0.0489)	0.2305*** (0.0274)
HP	0.0032 (0.0030)	0.0028 (0.0234)	0.0011 (0.0130)
Register	0.1126*** (0.0114)	0.4214*** (0.0831)	0.2196*** (0.0467)
Residence	-0.0607*** (0.0060)	-0.5476*** (0.0434)	-0.3021*** (0.0242)
Province	-0.0433*** (0.0055)	-0.4233*** (0.0408)	-0.2403*** (0.0230)
Independent variable			
IU	0.0744*** (0.0118)		
_cons	1.3978*** (0.0537)	4.6421*** (0.4643)	2.6451*** (0.2479)
R-squared	0.2127		
Pseudo R ²		0.5215	0.5179
AUC		0.9318	0.9318
N		10993	10993

Note: * p<0.10, ** p<0.05, *** p<0.01; Numbers in parenthesis are standard error.

Table B2. Kernel matching, k-nearest neighbor matching and radius matching balance test.

Sample	Pseudo R ²	LR chi2	P>chi2	MeanBias	MedBias
Unmatched	0.518	7796.04	0.000	58.6	43.5
Kernel matching	0.035	458.82	0.000	9.6	8.1
K-nearest neighbor matching	0.042	546.53	0.000	8.6	6.4
Radius matching	0.035	455.10	0.000	9.1	6.4

Appendix C

Table C1. The unmatched results of subdivided sample analysis.

Heterogeneous variable	Group standard	Pr-PEB		Pu-PEB	
		Unmatched		Unmatched	
		ATT	t-value	ATT	t-value
Age	Young	0.2816 (0.0148)	18.97***	0.1509 (0.0115)	13.09***
	Middle-age	0.2802 (0.0171)	16.39***	0.1843 (0.1184)	15.57***
	Old	0.3823 (0.0286)	13.41***	0.1517 (0.0164)	9.26***
Gender	Male	0.2297 (0.0125)	18.41***	0.1510 (0.0090)	16.87
	Female	0.3184 (0.0121)	26.37***	0.1653 (0.0081)	20.36***
Edu	Primary school or below	0.1146 (0.0237)	4.83***	0.0806 (0.0131)	6.16***
	Junior high school	0.0600 (0.0162)	4.07***	0.0438 (0.0105)	4.16***
	Senior high school or above	0.1304 (0.0173)	7.52***	0.1227 (0.0149)	8.21***
Residence	Urban	0.1635 (0.0126)	13.02***	0.1483 (0.0099)	15.00***
	Rural	0.2118 (0.0126)	16.78***	0.1209 (0.0080)	15.13***

Note: * p<0.10, ** p<0.05, *** p<0.01; Numbers in parenthesis are standard error.