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Exploring the Relationship between E-Government Development and Environmental Sustainability: A Study of Small Island Developing States

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Abstract: Small island developing states (SIDS) are one of the most vulnerable countries for environmental sustainability in the world. To maintain environmental sustainability, the SIDS governments are pursuing many e-government projects, but there is much debate on its effectiveness. In the absence of empirical evidence, this study conducts quantitative analysis to estimate the effects of e-government development on environmental sustainability. Utilizing a panel dataset, we found that the development of e-government not only has direct effects on environmental sustainability, but also indirect effects through the enhancement of government effectiveness. This study emphasized the importance of contingent or intermediary factors in the study of e-government effectiveness. Additionally, after reviewing potential variables, we recommend the effectiveness of government as an important intermediary variable for the environmental sustainability in developing countries, such as SIDS.

Keywords: e-government development; environmental sustainability; government effectiveness; small island developing states

1. Introduction

The environmental sustainability of small island developing states (SIDS) is in serious jeopardy. Sea-level rise, deforestation, overexploitation of land, pollution, habitat degradation, and climate change have made them susceptible to environmental disasters. They are extremely vulnerable in light of multiple environmental risks, in fact, according to [1], SIDS face more than 1.5 times the global average of environmental risks.

With the dramatically increasing threats to environmental sustainability, there has been, in recent decades, a corresponding increase in information and communications technology (ICT), which many see as providing e-government solutions for a sustainable environment as one of the main tools for coping with environmental risks [2–5]. While still in the early stages of e-government development, SIDS have made progress towards enhanced environmental sustainability through e-government. For example, the Timor-Leste government, together with other maritime Southeast Asia governments, has set up an alert messaging service that broadcasts severe weather warnings for events that might pose environmental risks. In Fiji, the government provides farmers with the information on the correct use of fertilizer and insecticides for the environmental protection of land. Many SIDS governments have introduced green ICT equipment for government operations and have implemented Information Network Village projects that provide villagers with information and awareness on environmental sustainability to establish and support self-sustainable communities.

Examples of such investments in e-government for sustainable environment can be found across most SIDS. As these states, with limited resources, make such investments to promote

national development, it is important to examine how these resources are contributing to environmental sustainability.

Although the 2003 World Summit on the Information Society emphasized the role of e-government development strategies to support sustainability, there is not much research on the relationship between e-government and environmental sustainability. For example, Estevez et al. [6] indicated that research at the intersection of e-government and sustainable development is very few. Furthermore, the research that does exist has contradictory conclusions about the effectiveness of the strategies [7–9].

It is perhaps too early to see the effects of e-government on environmental sustainability. Furthermore, e-government, by itself, may not be a dominant strategy and it requires favorable social conditions to be effective. Achieving environmental sustainability is a complex and slow process where it is difficult to isolate the contribution of individual strategies. It is quite likely that e-government also matures social conditions that can improve environmental sustainability. In other words, the development of e-government not only has a direct effect on environmental sustainability, but it also contributes indirectly through improved social conditions.

Whatever the nature of the relationship, positive or negative, it is clear that there is no simple cause-effect relationship between e-government development and environmental sustainability [10]. Krishnan and Teo [3] note that "there is a dearth of quantitative empirical studies examining IT-environmental sustainability linkage from a global perspective". Estevez and Janowski [6] suggest the development of a new research field such as electronic governance for sustainable development. It is in this context, that we explore the direct and indirect effects of e-government on environmental sustainability in SIDS.

The structure of this paper is as follows: We begin with a review of the literature on the role of e-government development on environmental sustainability. In the next section we discuss our research design, models, and hypotheses included in the empirical analysis of panel data on SIDS. We conclude with a discussion of the lessons learned from this analysis of the various paths linking e-government development to environmental sustainability.

2. Literature Review on the Effects of E-Government on Environmental Sustainability

2.1. Definition of Environmental Sustainability

The Brundtland Report [11] describes sustainability as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs." The UN [12] resolution described economic, social, and environmental sustainability as the three pillars of sustainability. Along with these dimensions, the 2005 World Summit on Social Development identified sustainable development goals, such as economic development, social development, and environmental protection.

Over the years, scholars have offered a number of definitions of environmental sustainability. Daly [13] defined environmental sustainability in terms of renewable resources, sustainable waste disposal, and the development of renewable substitutes for nonrenewable resources. The basic principle underlying sustainability, according to Bansal [14], is that human activities should not erode the Earth's land, air, and water resources. In this study we use Morelli's concept [15] of environmental sustainability based on his comprehensive review of the literature on the relationship between ecological sustainability and environmental sustainability. He states that environmental sustainability is "meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them" (p. 23). More concretely, according to him, environmental sustainability is "a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity" (p. 23).

SIDS face "unique and particular vulnerabilities and that they remain constrained in meeting their goals in all three dimensions of sustainable development (This is an excerpt from the outcome document of the third international conference on SIDS, SIDS Accelerated Modalities of Action-Samoa Pathway)". In particular, the environmental sustainability challenges SIDS face include isolation from major markets, small domestic market and resource base, absence of economies of scale in the provision of public services, and susceptibility to natural disasters [16]. Table 1 presents the World Risk Index data showing the severity of environmental vulnerability of SIDS in the Pacific and Atlantic, Indian Ocean, Mediterranean, and South China Sea (AIMS).

Table 1. World risk index of SIDS in the Pacific and AIMS.

Country	World Risk Index	Exposure	Vulnerability
Vanuatu	36.31 (1)	63.66 (1)	57.04 (56)
Tonga	28.62 (2)	55.27 (2)	51.78 (73)
Solomon Islands	18.15 (6)	29.98 (13)	60.55 (50)
Timor-Leste	17.13 (9)	25.73 (18)	66.59 (23)
Papua New Guinea	15.81 (12)	24.94 (13)	63.38 (36)
Mauritius	15.39 (13)	37.35 (7)	41.21 (122)
Fiji	13.69 (15)	27.71 (14)	49.4 (85)
Guinea-Bissau	13.34 (17)	19.65 (27)	67.88 (19)
Cape Verde	10.88 (32)	20.26 (25)	53.72 (68)
Comoros	7.45 (68)	10.97 (112)	67.91 (18)
Samoa	4.51 (119)	9.1 (141)	49.58 (84)
São Tomé and Principe	3.4 (143)	5.81 (164)	58.55 (53)
Seychelles	2.6 (156)	5.99 (162)	43.46 (115)
Singapore	2.54 (158)	7.82 (153)	32.47 (155)
Bahrain	1.81 (166)	4.27 (167)	42.44 (121)
Kiribati	1.78 (167)	3.05 (170)	58.32 (53)
Average	12.09	21.97	54.02

Source: Alliance Development Works and UNU-EHS, World Risk Report 2012 [2].

The high scores (Table 1) are indicative of the high exposure of SIDS to natural hazards such as earthquakes, cyclones, flooding, drought, and sea level rise. With climate change, deforestation, overexploitation of land, and plastic pollution among the largest threats to environmental sustainability, SIDS need to conserve and sustainably use the oceans, seas, and marine resources. In response to these sustainability issues, the SIDS governments have begun to invest in e-government as a strategy towards enhancing sustainable development. The use of information and communication technologies can help overcome some of the challenges due to villages and people being scattered and widely dispersed resulting in limited citizen participation that further hinders effective policy implementation. Lack of resources further limits the ability of citizens to prepare for unanticipated natural disasters and subsequent environmental degradation.

2.2. The Role of E-Government for Environmental Sustainability

Even though the introduction of e-government is not a panacea for the problems that governments face [3], dissemination of information and communication technology can enlarge opportunities for citizen engagement on the issues of environmental sustainability. Al-Khouri [7] maintained that "environmental sustainability is the soundless side in e-government initiatives" (p. 206). Additionally, Krishnan and Teo [3] argued that e-government development in a country as one of the major initiatives can serve the environmental objectives of its government. Similarly, Srivastava and Teo [17] see national information system innovations as a valuable resource to national competitive advantage in terms of environmental sustainability. Janowski (2015) [9] presented four different stages of e-government evolution: digitization, transformation, engagement, and contextualization. Of these, particularly noteworthy stages in relation to this study are the transformation stage and contextualization stage. In transformation stage, e-government impacts government organizations,

while it has impacts sectors and communities in contextualization stage. The impact of e-government development on the government effectiveness assumed in this study corresponds to the second stage of e-government evolution by Janowski (2015) [9]. In contextualization stage, e-government has three features: e-government transforms internal government, it transforms external relationships, and it depends on the context that it is applied. One example at the contextualization stage presented by [9] is that e-government is utilized to achieve sustainable development goals. As Janowski [9] indicated, the development of e-government is in various phases, and we can assume that it contributes to greater government effectiveness and further to environmental sustainability as the phase develops.

In terms of sustainable goals, Estevez and Janowski [6] emphasized the role of electronic governance for sustainable development. According to them, Electronic Governance for Sustainable Development (EG4SD) refers to "ICT-enabled governance of the transition towards Sustainable Development." (p. S96) Adopting a comprehensive approach to EG4SD literature review, they presented the current status of EG4SD research. In particular, Estevez and Janowski [6] found that, regarding research problems by the four dimensions of sustainable development, 33% of the research has to do with social-related problems, 28% with institution-related problems, 20% with economy-related problems, and 19% with environment-related problems. They also found that there have been many studies in both domains of e-government and sustainable development, respectively, but the studies are fragmented within each domain and there is a lack of fusional studies. This paper lies in the intersection of ICT, government, and sustainable development consisting of EGOV4SD research. In this regard, this research meets a request for an EGO4SD research as research domain suggested by [6].

Additionally, Estevez et al. [18], Janowski [19], and Larsson [20] suggested electronic government research for sustainable development. Despite many studies on the relationship between e-government and environmental sustainability are conducted qualitatively, there are very few empirical studies on the relationship. Although limited in quantity, here we will review the current studies that have examined the impact of e-government on environmental sustainability. This literature review consists of two parts: the first part examines the literature on the positive and negative effects of e-government on environmental sustainability. These studies suggest contradictory results on the direction of the impacts, but all of them share a limitation in common that they consider only the direct relationship between e-government development and environmental sustainability. The second part concerns the moderating effects that have been highlighted in recent studies on the effects of e-government. If previous studies only looked at the direct link between e-government and environmental sustainability, the new research trend considers indirect linkages through various conditional variables. This new research trend goes beyond the positive/negative dichotomy of the existing research by considering the mechanism by which e-government impacts environmental sustainability.

First, we will review studies that have analyzed the direct relationship between e-government development and environmental sustainability. Many studies introduced the e-government initiatives to improve environmental sustainability and reported the impacts of e-government on environmental sustainability [7,21–24].

To summarize the previous studies on the positive effects of e-government development on environmental sustainability, the mechanisms by which e-government positively affects environmental sustainability are as follows: by savings in costs due to transportation obviated by the need to visit government offices, and in savings in fossil fuel usage, the reduction of paper [7]; by lowering their energy consumptions and carbon footprints [22]; and/or providing greater opportunities for agencies to share and re-use technology, and reducing overall infrastructure costs [21]. Matthews [23] and Ogbom et al. [24] see ICT as also reducing socio-economic inequality and environmental damage.

On the other hand, there are many studies that pay attention to the negative relationship between e-government and environmental sustainability. Al-Khouri (2013) [7] argues that with the help of ICT, the world has achieved significant growth, but has increased the social costs that potentially have enormous negative impacts on the environment. By examining the impacts of ICT on global

carbon footprints and emissions, he argues that environmental sustainability should be a key principle driving e-government initiatives. Various research studies support the argument that governments have failed in their strategic endeavors to include environmental sustainability in their e-government efforts [7,22,25].

With respect to the three Australian cases, Haigh and Griffiths (2008) [2] found that even if the environmental impact of e-government is considered at top-tier strategies, those strategies would be largely eliminated at the implementation stage. They emphasized the importance of strategic alignments across different layers of e-governments for environmental sustainability.

The above studies have in common that they assume the direct relationship between e-government and environmental sustainability. However, studies began to explore possible moderating variables or the conditions in which e-government can contribute to environmental sustainability requesting further investigation. Haigh (2004) [26] also explained the contradictory effects of e-government on environmental sustainability in the literature. Further, he maintained that there is a very large research gap in the e-government literature and argued that the question of the relationship between e-business and environmental sustainability is to explore contingency factors that would moderate the size and the direction of e-business impacts.

Krishnan and Teo (2011) [3] argued that moderating factors, which are often missing, could provide a possible environmental sustainability linkage considering the importance of contingency factors between the two. In a similar vein, Elliot (2011) [27] emphasized that "researchers may find numerous situations in which the moderation is significant, but the direct effect is not". APC (2011) asked to include not only sector-specific issues, such as climate change and e-waste, but to take a broader approach encompassing even organizational practices to understand environmental sustainability.

Using structural modelling, Krishnan et al. (2013) [3] examined the effects of e-government on the environmental degradation of nations. According to them, the maturity of e-government did not directly affect environmental degradation. However, e-government maturity has been shown to restrain the occurrence of corruption and, thus, negatively and indirectly affect environmental degradation. They concluded that the impacts of e-government could be realized via other context variables or intermediary variables. Kumar and Best (2006) [4] and Heeks and Bhatnagar (1999) [10] proposed a number of critical success/failure factors that may explain the adverse relationship between e-government programs and environmental sustainability.

Krishnan and Teo (2011) [22] found moderating effects of "national environmental factors" between the e-government and environmental sustainability relationships. Three dimensions of the contingency factors confirmed by them are quality of human capital (social dimension), quality of public institutions (institutional dimension), and macro-economic stability and GDP per capita (economic dimension). While these findings are important to advance the research on the relationship between e-government and environmental sustainability, certain limitations are shown. First, human capital is one of measures capturing the development of e-government. Second, economic dimensions used a typical measure of economic sustainability. Despite of these shortcomings, the finding of quality of public institutions as an important moderating variable shed a light on the further study. Additionally, they utilized archival data from 122 countries, but they are cross-sectional, which is hard to catch long-term interactions among e-government development, environmental sustainability, and their moderating factors.

Many scholars in public administration emphasized the importance of public institutions in achieving the purposes of e-government initiatives [17,28–32]. Chen et al. (1999) [33] showed that the adoption of environmentally sustainable products and practices can be driven by the institutional forces in the form of mimetic and coercive pressures. Paavola (2003) [34] also indicated that quality of public institutions, among others, is an important source of vulnerability to climate change. Haldenwang (2004) [31] emphasized that e-government can be a tool for promoting good governance

and strengthening policy actors. Additionally, West (2004) [32] carefully suggests that e-government development can enhance democratic responsiveness and public trust in government effectiveness.

In summary, the review on the current literature of the impact of e-government on environmental sustainability implies that the effects of e-government can be realized through various paths, and researchers should pay attention to various possible paths. Careful consideration of the intermediary variables in the various paths is very important for accurately estimating the effects of e-government development on environmental sustainability. In the following section, we will conduct an empirical analysis of the impact of e-government development in SIDS considering various paths of influence.

3. Research Design

3.1. Analytic Model and Hypothesis

3.1.1. Analytic Model

Based on the above literature review on the relationship between e-government development and environmental sustainability, we have established the following analytic model to estimate the direct and indirect effects of e-government development on environmental sustainability. If you see Figure 1, the development of e-government has a direct impact on environmental sustainability. In addition, the development of e-government affects government effectiveness which, in turn, affects environmental sustainability. In other words, e-government development has an indirect effect on environmental sustainability by enhancing government effectiveness. Through this modeling, we can verify the mechanisms in which the e-government development impacts on environmental sustainability, which has been controversial in the existing literature. The analytic model implies that the impacts of e-government development on environmental sustainability may occur via government intervention or without any government intervention. We will empirically test the relationships below.

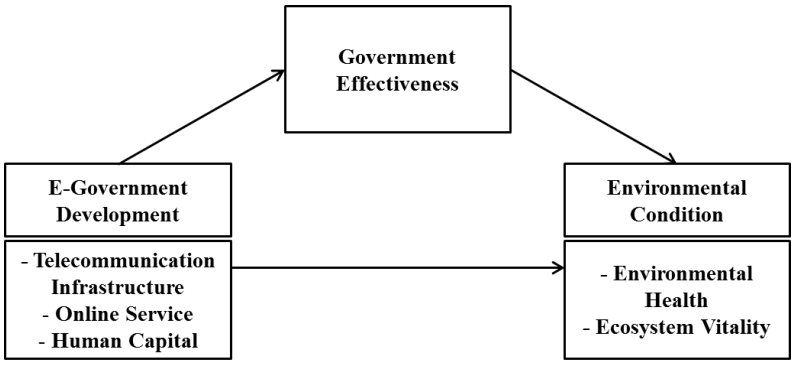

Figure 1. Analytical model.

3.1.2. Hypothesis

In the above, an analytical model was set up to estimate the direct and indirect effects of e-government on environmental sustainability. Based on the model, this study established the following hypotheses. First, to estimate the direct effects, the hypothesis would be:

Hypothesis 1. *E-government development in a country will directly influence environmental sustainability.*

As mentioned earlier, many studies support this relationship [3,7,21–24].

In order to estimate the indirect effects of e-government development on environmental sustainability, we established the following hypothesis.

Hypothesis 2. *The relationship between e-government development and environmental sustainability is moderated by government effectiveness. The relationships become stronger when the quality of public institutions is high, and becomes weaker when the quality is low.*

As reviewed in the literature review, the relationship between e-government development and environmental sustainability is not simply linear. Various variables are introduced as intervening variables that mediate the relationship between e-government development and environmental sustainability. Of these variables, we are focusing on the variable of government effectiveness. For environmental sustainability, it is often said that the government's ability to establish and enforce effective policies is important. Especially in developing countries where economic resources are scarce, the role of the government is crucial in creating a sustainable society. In other words, how effectively the government operates can make a substantial difference in terms of sustainable society.

3.1.3. Samples

For this study, we utilized the 22 SIDS in the Pacific and Africa, Indian Ocean, Mediterranean, and South China Sea (AIMS) regions as a sample. There are currently nine states in AIMS and 20 states in the Pacific region, of which there are 22 member nations. Since we obtained data with the help of the United Nations, we could use 22 SIDS with UN membership. The samples are the Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Palau, Papua New Guinea, Samoa, Sao Tome and Principe, Solomon Islands, Timor-Leste, Tonga, Tuvalu, and Vanuatu in the Pacific region, and Bahrain, Cape Verde, Comoros, Guinea-Bissau, Maldives, Mauritius, Seychelles, and Singapore in the AIMS region. For these 22 states, we collected data from 2002 to 2012 and composed a panel dataset for the analysis. In this study, the whole Pacific and AIMS SIDS country are basically assumed as a population. However, SIDS faced with their unique conditions may be more sensitive to the direct and/or indirect effects of e-government development comparing countries in other regions or developmental status.

3.2. Measures of the Variables

3.2.1. Measures of Environmental Sustainability

Consistent with existing studies, we used secondary indicators of environmental sustainability. In this study, we used the Environmental Performance Index (EPI) to measure environmental sustainability as shown in Table 2 below. Since its first publication in 2002 to quantify the environmental performance of a country, EPI has been used to measure the environmental goals of the United Nation's Millennium Development Goals. Since then, EPI has become widely used in the international community as a representative indicator of environmental conditions of nations, especially in developing countries. The Yale Center for Environmental Law and Policy (YCELP) and the Center for International Earth Science Information Network (CIESIN) have biennially reported the EPI. The EPI is comprised of environmental health and ecosystem vitality, covering environmental risk exposure, air pollution, water resource and sanitation, nitrogen from agriculture, forest preservation, fish stocks, biodiversity and habitat, and climate and energy. We adopted back-casted data from 2002 to 2012 released in 2014. The range of EPI is from 0 to 100.

Table 2. Overview of Environmental Performance Index (EPI).

Objective	Issue Category	Indicator
Environmental Health (50%)	Health Impacts (33%)	Environmental Risk Exposure (100%)
	Air Quality (33%)	Household Air Quality (30%)
		Air Pollution—Average Exposure to PM2.5 (30%)
		Air Pollution—PM2.5 Exceedance (30%)
		Air Pollution—Average Exposure to NO2 (10%)
	Water and Sanitation (33%)	Unsafe Sanitation (50%)
		Drinking Water Quality (50%)
Ecosystem Vitality (50%)	Water Resources (25%)	Wastewater Treatment (100%)
	Agriculture (10%)	Nitrogen Use Efficiency (75%)
		Nitrogen Balance (25%)
	Forests (10%)	Change in Forest Cover (100%)
	Fisheries (5%)	Fish Stocks (100%)
	Biodiversity and Habitat (25%)	Terrestrial Protected Areas (National Biome Weights) (20%)
		Terrestrial Protected Areas (Global Biome Weights) (20%)
		Marine Protected Areas (20%)
		Species Protection (National) (20%)
		Species Protection (Global) (20%)
	Climate and Energy (25%)	Trend in Carbon Intensity (75%)
		Trend in CO2 Emissions per KWH (25%)

Source: 2016 EPI Raw Data [35].

3.2.2. Measures of E-Government Development

The E-Government Development Index (EGDI), which is published every two years by the United Nations, is the most widely-used measure for the national capacity of the e-government development. The EGDI covers the largest number of countries, as it provides a ranking of e-government development for all UN member states. This is why most of the studies use EGDI to measure the e-government development of a nation. The EGDI consists of three dimensions ranging from 0 to 1: ICT infrastructure (TII), e-Public Service (OSI), and Human Capital Index (HCI).

ICT infrastructure reflects the telecommunication infrastructure index and a composite index of the proportion of internet users, the proportion of fixed phone lines, the proportion of mobile subscribers, the proportion of fixed Internet subscribers, the proportion of fixed broadband subscriptions, and wireless broadband subscriptions. Data on TII are from the International Telecommunication Union's ICT development Index (IDI).

E-Public Service is an online service index measuring national websites' service levels, such as governmental portals and ministries' websites of education, labor, social services, health, finance, and environment. This index is an indicator to assess whether the government's online service has been expanded to some extent.

The final component of the EGDI is the human capital index, which is a composite index consisting of the weighted average of adult literacy rate, primary, secondary, tertiary enrollment, and expected years of education. This index captures the ability to use e-government representing a proxy for e-awareness.

For the Pacific and AIMS SIDS, the EGDI increased by 0.0604 points from 2003 to 2014 (The UN E-Government Survey covers all UN member states, but regarding SIDS, it contains only 38 UN member states' data out of 52 SIDS: 22 states of them are in the Pacific and AIMS, while 16 states are in the Caribbean). Figure 2 shows there were two times of noticeable growth in the EGDI between 2005 and 2008, and between 2010 and 2012, both in line with the global trend. However, there was a decline in the EGDI between 2012 and 2014 in all regions including Africa, the Americas, Asia, Europe,

and Oceania. This decline may be caused by the changes in the components which constitute the human capital index and the telecommunication infrastructure index.

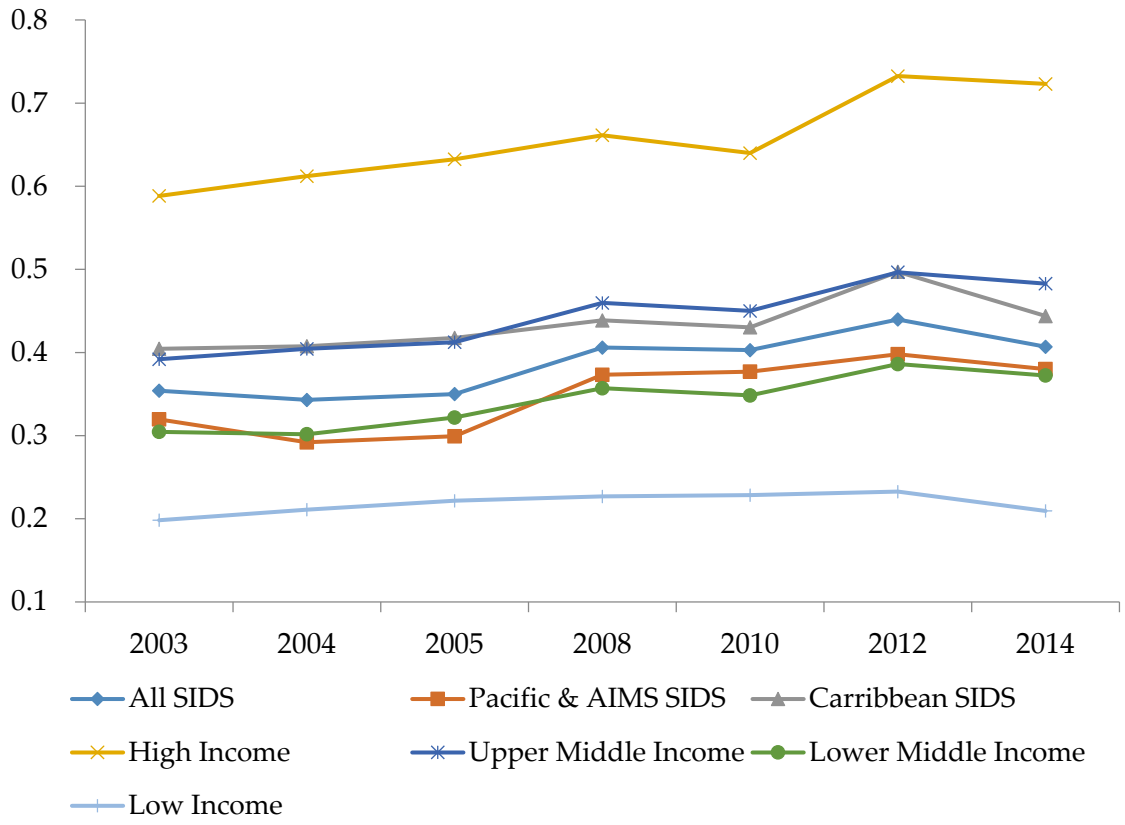

Figure 2. Regional comparison of EGDI. Source: UN E-Government Survey 2003–2014.

According to the E-Government Survey 2014, the average of 38 SIDS is 0.469 point. The EGDI of the Pacific and AIMS SIDS is 0.3800 points, which is not only lower than the world average (0.4712), but also than that of Caribbean SIDS (0.4439). The average of all SIDS is placed between the lower middle income countries (0.3723) and upper middle income countries (0.4828). However, the average of the Pacific and AIMS SIDS are relatively close to lower middle income countries while that of Caribbean SIDS is close to upper middle income countries.

3.2.3. Measures of Government Effectiveness

Government effectiveness measures the quality of public service provision and the independence of government from political pressures. It captures the quality of policy formulation and implementation, particularly for the delivery of public goods as well as the credibility of government commitment to policies. Government effectiveness measures are one of the six dimensions of governance used by the World Bank, and it has been constructed by aggregating several indicators such as quality of public services, the quality of civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to policies. For this measure, we utilized the World Bank's Worldwide Governance Indicators widely used in many studies [16,36–39].

Figure 3 shows the trend of the government effectiveness index in the Pacific and AIMS SIDS. According to the Worldwide Governance Indicators (WGI) of the World Bank, the average of the indicators have been negative. The indicators' values diminished from 2005 to 2009. Even though it seems that the government effectiveness has gotten better since 2009 or 2010, the level of government effectiveness in the Pacific and AIMS SIDS is consistently below the world average.

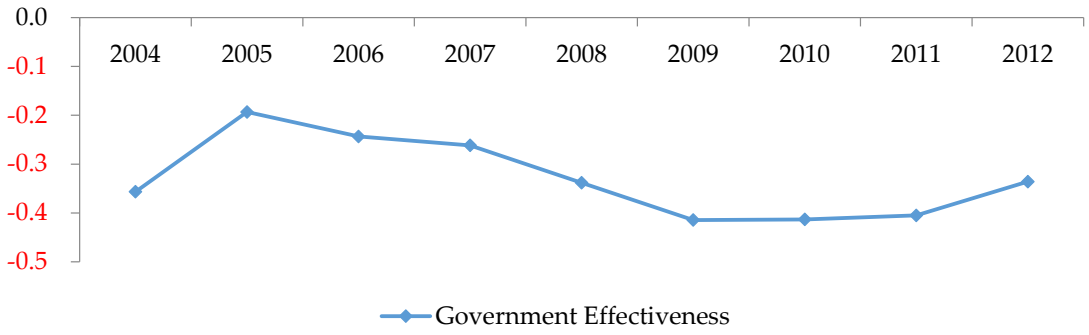

Figure 3. Trends in Government Effectiveness of SIDS. Note: Data do not include all SIDS. Source: World Bank's Worldwide Governance Indicators (WGI).

3.2.4. Measures of Control Variables

Our models include two control variables: population density and outlier countries. The use of population density is to control for differences in the burden of ecosystem and environmental management, which are assumed to affect environmental conditions. The use of population density as a control variable is consistent with previous studies [2]. Among the SIDS, Singapore and Bahrain have achieved exceptionally higher performances regarding e-government and economy than the others. To control the two countries' exceptionality, the equations include a dummy variable for these outlier countries.

3.3. Empirical Models Andanalytic Method

In this study, we set up three empirical models to explore the direct and indirect effects of e-government development on environmental sustainability. The first model estimates the direct impact of e-government development on government effectiveness. The second model was set up to estimate the direct impact of e-government on environmental sustainability. Finally, the third model was established to estimate the impact of e-government development on environmental sustainability moderated by government effectiveness.

Step 1:

$$\text{Government effectiveness}_{i.\ t} = a_0 + a_1 \ln(EGDI)_{i,\ t} + a_2 \ln(population\ density)_{i,\ t} + a_3 outlier + \epsilon_{i,\ t}$$

Step 2:

$$\text{EPI}_{i.\ t} = a_0 + a_1 \ln(EGDI)_{i,\ t} + a_2 \ln(population\ density)_{i,\ t} + a_3 outlier + \epsilon_{i,\ t}.$$

Step 3:

$$\begin{aligned}\text{EPI}_{i.\ t} = a_0 + a_1 \ln(EGDI)_{i,\ t} + a_2 &\text{Government effctiveness}_{i,\ t} \\ + a_3 \ln(population\ density)_{i,\ t} &+ a_4 outlier + \epsilon_{i,\ t}\end{aligned}$$

where EGDI represents e-government development index and EPI indicates measures for environmental sustainability of a country. In subscript, i represents countries and t is the time in years, while a represents regression coefficients and ε is the error term. We established the first equation to estimate the effects of e-government on government effectiveness and the second equation to estimate the effects of e-government on environmental sustainability. The last equation estimates the effect of government effectiveness on environmental sustainability. The direct effect of e-government development on environmental sustainability can be obtained from the second equation. The indirect effect that the development of e-government contributes to environmental sustainability through improvement of government effectiveness can be obtained by multiplying the coefficient a_1 from the first equation, which shows the impact of e-government development on government effectiveness,

and the coefficient a_2 from the third equation, which shows the effect of government effectiveness on environmental sustainability.

For this analysis we used panel data, which is likely to involve autocorrelation (serial correlation) and heteroskedasticity. We, therefore, examined every model with the Wooldridge test for autocorrelation, with the Breusch-Pagan test and White's test for heteroscedasticity. When we detected autocorrelation and heteroscedasticity in any models, we applied feasible generalized least squares to correct the autocorrelation and heteroskedasticity.

For panel data analysis, it is recommended to consider the traits of individuals by using a random model or fixed model. However, the fixed model can be inefficient if the time range of the dataset has a short-term period. For this reason, we tried to control the traits of individual states by including the control variables into our models. As we mentioned above, we included population size and outliers (Singapore and Bahrain) as control variables.

4. Empirical Results

The following Table 3 shows descriptive statistics of the key variables used in the analysis. The average EPI score of the sample is 47.516 out of 100 points and the standard deviation is 11.549. The average of the government effectiveness index, which ranges from −1 to +1, of the sample is −0.076. It shows that the government of the sample SIDS lacks the capacities in good policy formulation and implementation, and quality public services provision. Finally, the average score of e-government development is 0.409 out of 1.000, which is about 15% lower than the world average (0.4712). As seen above, SIDS shows a low level of e-government development, on average. However, the e-government index has been continuously rising in recent years due to the introduction of many e-government projects.

Table 3. Descriptive statistics of key variables.

Variable	Average	N	S.D.
EGDI	0.409	169	0.150
Government effectiveness	−0.076	167	0.881
EPI	47.516	169	11.549
ln(Population density)	4.401	169	1.741
Population density	448.740	169	1335.677

Table 4 below shows the correlation among the main variables. All of the variables used in the analysis are positively correlated, and all correlation coefficients are statistically significant. In particular, the relationship between e-government development (EGDI) and government effectiveness and between EGDI and environmental sustainability (EPI) are highly correlated. In addition, the correlation coefficient of government effectiveness and EPI is the highest correlation among variables. Through this result, we can see that the development of e-government is positively related to government effectiveness and environmental sustainability. However, what is important is the mechanism of the impacts and the extent to which the development of e-government affects.

Table 4. Correlations of variables.

Variable	ln(EGDI)	Government Effectiveness	EPI	ln(Population Density)
ln(EGDI)	1			
Government effectiveness	0.676 ***	1		
EPI	0.614 ***	0.782 ***	1	
ln(Population density)	0.441 ***	0.474 ***	0.471 ***	1
Outlier	0.510 ***	0.468 ***	0.477 ***	0.620 ***

*** $p < 0.01$.

The analysis results are shown in Table 5. The results of the first step analysis show that the degree of development of e-government has a positive impact on government effectiveness. In other words, the development of e-government contributes to the improvement of government effectiveness. Logically, government effectiveness can also affect e-government development. However, many studies have examined the influence of e-government on government effectiveness, and this study also has the purpose of testing this relationship. In the future, it is necessary to study the direction of influence between the two variables, and care must be taken in interpreting the relationship between the two variables.

The results of the second step analysis suggest that the development of e-government has a positive and direct impact on environmental sustainability. In contrast to the concerns of some previous studies, the development of e-government has contributed to environmental sustainability even in the case of SIDS, in which social conditions are not favorable for implementing e-government projects.

In the last step model, we estimated the direct and indirect impacts of e-government development on environmental sustainability in an equation. As seen in the last column of the table, the development of e-government is estimated to have statistically significant, positive, direct, and indirect effects on environmental sustainability.

Table 5. Analysis to estimate moderating effects of government effectiveness on EPI.

Variable	Step 1 (Government Effectiveness)	Step 2 (EPI)	Step 3 (EPI)
ln(EGDI)	0.582 ***	2.043 ***	1.178 **
Government effectiveness	–	–	1.133 **
ln(population density)	0.086 ***	1.263 ***	1.555 ***
outlier	0.550 **	15.189 ***	13.942 ***
constant	0.121	43.351 ***	40.798 ***
N	167	169	167

** $p < 0.05$; *** $p < 0.01$.

The results show that the direct impact of e-government development on environmental sustainability is 1.178, and the e-government development has a positive effect on government effectiveness by as much as 0.582, while government effectiveness has a positive effect on environmental sustainability by as much as 1.133. As mentioned in Section 3.3, the indirect effect of e-government development on environmental sustainability can be obtained by multiplying these two estimates. The indirect effect that the development of e-government contributes to environmental sustainability through improvement of government effectiveness is 0.659 (= 0.582 × 1.133). In total, 1% of the increase in EGDI is estimated to raise EPI by 1.837 points. All of these estimates are statistically significant.

Figure 4 illustrates the direct and indirect impacts of e-government development on environmental sustainability.

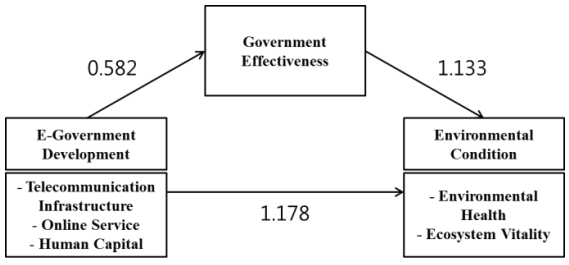

Figure 4. Empirical results of the analysis.

The results of this analysis suggest what previous studies have emphasized. Heeks and Bailur (p. 248) [40] argued that the findings in the literature of "technology determinism" understand that ICT always has a positive impact on society due to its unchanging features. However, they regard this tendency as "a naïve optimism" that fails to recognize that the impacts of e-government are also "largely the result of human agency shaped by social context". In a similar context, Gil-Garcia and Pardo (2005) [41] have argued that managerial, political, and legal factors are also important in ICT initiatives and can influence the results of an ICT projects. Estevez et al. [6,18] showed, through case studies, that e-government development can contribute to achieving sustainable development goals, including environmental goals.

Additionally, at the implementation stage, there are many factors, such as the types of bureaucracy [42], political and administrative support [43], leadership [44], and internal policy [45], which complicate the relationship. However, there is no consensus on a coherent set of plausible intervening or contextual variables that influence a relationship between e-government and environmental sustainability. Finding these variables needs further research, and government effectiveness can be a strong candidate.

5. Conclusions

Environmental sustainability in SIDS is inherently vulnerable. SIDS are very susceptible to climate change, deforestation, overexploitation of land, and natural disasters. Like other developing countries, SIDS are making efforts to secure environmental sustainability, as well as increase government effectiveness through e-government. This study empirically analyzes the mechanisms by which e-government development impacts on environmental sustainability in SIDS.

Utilizing a panel dataset, we found that e-government development has direct and indirect effects on environmental sustainability. The estimate of the direct effect is 1.178, and the indirect effect of e-government development on environmental sustainability through the promotion of government effectiveness is 0.659. Therefore, the total effect of e-government development on environmental sustainability is 1.837. This means that, as the EDGI increases by 1%, environmental sustainability increases by 1.837 points.

This study is significant in that it is one of few studies that empirically analyzes the effects of the development of e-government on environmental sustainability of SIDS using panel data. In addition, this study is meaningful in that it is a study that estimates indirect effects, as well as direct effects of e-government development. We have obtained the following implications for the study in the future:

First, we have presented empirical evidence that the development of e-government contributes to environmental sustainability. As we have seen in the literature review, there are contradictory arguments about the impact. This study verified its effectiveness using the most extensive data that are currently available. We hope that this research will be useful in further discussions.

Second, this study emphasized the importance of contingent factors in the study of e-government effectiveness. Therefore, studies on the effectiveness of e-government should actively accommodate not only direct, but also indirect, effects through intermediary variables. We need to try to find suitable situational factors for the dependent variable we have interest in.

Third, after reviewing potential contingent variables, we find that the effectiveness of government is very important for the environmental sustainability in developing countries such as SIDS. This is a natural consequence of the fact that, in most developing countries, human and material resources tend to gather in the public sector and governments often have enormous regulatory powers. Therefore, we recommend that further studies utilize the government effectiveness factor as an intermediary variable.

We would like to emphasize that the results of the empirical analysis derived from this study have been tested in the context of SIDS. As mentioned in the literature, there is a lack of empirical analysis on the direct and indirect effects of e-government development on environmental sustainability. We expect that the accumulation of empirical research on this topic will lead to a more general conclusion about the relationship between the two variables. It is necessary to study more the effects of e-government

on environmental sustainability according to the different phases of e-government development or the specific contexts of developing countries. The accumulation of these studies will make it possible to generalize the conclusions drawn from this study.

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