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Improving ICTs (Mobile Phone and Internet) for Environmental Sustainability in the Western Balkan Countries

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Abstract: The aim of this paper is to replicate an existing study using the Generalized Method of Moments on the impact of ICT penetration (Mobile Phone and Internet) in Western Balkan countries on environmental sustainability through changing CO_2 emissions for the period 2000–2015. A two-step system GMM method is used to handle both endogeneity of the independent and persistency of the dependent variables. Two important findings are derived: First, we find that mobile phones have a positive impact, whereas the Internet has a positive but insignificant impact on CO_2 emissions per capita in noninteractive models. The impact of ICTs is insignificant as far as CO_2 emission from liquid fuel consumption is concerned in noninteractive specifications. Based on this finding, we suggest policymakers of Western Balkan countries follow interdisciplinary policies and strategies considering ICTs such as Internet penetration to mitigate CO_2 emissions. Second, in interactive models, all marginal effects are negative, and in one specification the impact is statistically significant. We argue that increasing Internet penetration has a negative net effect on CO_2 emissions from liquid fuel consumption. By calculating the policy threshold for this net effect, we discuss the practical implications for policy making in Kosovo where the average Internet penetration is below this threshold.

Keywords: CO_2 emissions; ICT; Western Balkan countries; two-step system GMM; sustainable development; environmental sustainability

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1. Introduction

Today, Information and Communication Technology (ICT) are considered as both enablers and drivers of sustainable solutions. ICT continues to transform the way we live and work around the world. ICT is a key driver of growth and employment, improving efficiency and productivity, creating jobs, and supporting business models that recognize information portability, workforce migration, and resource decentralization. Additoinally, it has the potential to reduce the energy consumption of carbon emissions by using ICT in more efficient facilities management [1]. A wide range of new technologies can be used to address the issues referring to climate change. For instance, frontier technologies that refer to new, innovative, and disruptive technologies can protect the environment and tackle climate change. This way, the following eight key emerging technologies can tackle climate change: artificial intelligence (AI), Internet of Things (IoT), 5G, clean energy technology, digital twins, robotics, Space 2.0 technologies, as well as digitalization and Big Data within cities and urban regions [2]. To make ICT work for global environmental sustainability, there is a need for more proactive political and social shaping of the digitization process [3]. At the global level, governments have been engaged to encourage policies towards a sustainable environment through Sustainable Development Goals (SDGs) for the main determinants of carbon dioxide (CO_2) emissions [4].

There is a debate on the positive and negative effects of ICTs on the environment. However, at the academic level, there are efforts to provide scientific evidence on the positive aspects of ICT on the environment, especially on securing environmental sustainability. Although, in terms of production, it is considered that ICT is one of the sources of environmental pollution, through the application of new technologies it is considered that ICT can contribute to environmental sustainability through decreasing CO_2 emissions. Innovative technologies can be applied to creating smarter cities, transportation systems, electric networks, and energy-saving gains [5]. Although the issue of fighting climate change is quite challenging, there is a lot of research being carried out on how to address its complexity and how to combat it. The central question is how to promote environmental sustainability. Environmental sustainability can be encouraged by using education and clean technology investment to reduce carbon emissions [6].

There is evidence that environmental pollution can be reduced via new technologies. For instance, the use of ICT in the transportation sector can reduce pollution. The results confirm that ICT has the potential to lessen pollution if it is well used in the freight transport sector that includes inland, rail, and air. To enhance the environment, phones speed up interaction with intermodality and both telephones and mobile phones are quite effective to achieve environmental sustainability. This is especially relevant for the rail and the inland transport sectors, while the Internet yields its best results in the air transport sector [7].

When it comes to the suitability of ICT for environmental sustainability, it is confirmed for low-income developing countries, but not for high-income developing countries. In this regard, it is important that the designed ICT policies promote the development of environmental sustainability [4].

A study that examines how increasing ICT penetration in sub-Saharan Africa (SSA) can contribute towards environmental sustainability by decreasing CO_2 emissions shows that ICT (i.e., mobile phones and the Internet) has no significant effect on CO_2 emissions. Second, according to interactive regressions, increasing ICT has a net positive effect on CO_2 emissions per capita, whereas increasing mobile phone diffusion has a net negative effect on CO_2 emissions from liquid fuel consumption [8]. The ICT has a positive and significant effect on sustainable development, and the policymakers need to address this by using its potential for further implementation of the agenda on sustainable development [9].

An article that examines the link between carbon dioxide emissions, energy consumption, and real GDP for 12 Middle East and North African countries over the period 1981–2005 found that CO_2 emission reductions per capita have been achieved in the MENA region, even while the region exhibited economic growth [10]. When evaluated in both ICT Internet connection and ICT mobile phones, ICT has negative and considerably increasing environmental sustainability or lowering emissions [11].

The moderating impacts of renewable energy investment and governance quality on the connection between environmental deterioration and life happiness were investigated using an empirical approach. In emerging countries, good governance could be used as a policy component to mitigate the detrimental impact of environmental deterioration on life satisfaction [12]. Political stability, good governance, and financial development are all important factors in supporting renewable energy production in the Middle East and North Africa [13].

This empirical research is motivated to address three main concerns in the policy and scholarly written articles. First, the Western Balkan countries' adoption of EU legislation on the environment as they aim to join the EU. Second, rising concerns about global warming and environmental sustainability and finding interdisciplinary strategies to tackle this problem. Finally, the lack of empirical research in this area in the literature.

First, as the Western Balkan countries aim to join the European Union (EU) in the future, they have the responsibility to implement the EU legislation about the environment. To this extent, as a first concern, is the issue of decreasing the emissions of air pollutants and health gases (GHG), which is connected to energy, transport, and health policies, among others. However, implementation of the EU acquis on environment and climate in WB differs. It ranges from the initial phases of implementation to more advanced levels. Usually, the air pollutants, emitted mainly by human activities such as industry (including electricity production), household heating, and transport are usually above the country limits. Meanwhile, energy and transport are the main sources of GHG in the WB countries [14]. The highest level of pollution comes from the energy sector, mainly coal. On the other hand, there is a lack of systems to monitor, report, and verify greenhouse gas emissions [15].

Second, the Western Balkan countries are in the process of adopting the needed legal framework and necessary strategies regarding climate change mitigation, but the implementation is still not at satisfactory level. The adoption strategies need to include switching to power plants using cleaner energy resources, concrete policy plans for economic development, as well as the identification of concrete government support [16]. Although the new air pollutions standards should have contributed to lowering the release from coal plants across Western Balkan countries, the emissions of sulphur dioxide from coal power plants breached the legal limits. This is the case for the plants included in the National Emissions Reduction Plans (NERPs) of Bosnia and Herzegovina, Kosovo, North Macedonia, and Serbia. In March 2019, The Energy Community Secretariat opened a dispute settlement against Bosnia and Herzegovina, Kosovo, North Macedonia, and Serbia. This was due to the breaches of the NERP pollution limits in 2018 and 2019 [17]. As a result, air protection and global warming should be handled simultaneously through policies and measures established through an interdisciplinary framework [18].

Third, to the best of our knowledge, there is no paper in the literature that studies how improving ICTs (mobile phone and internet) has an impact on environmental sustainability through the reduction in CO_2 emission per capita and from liquid fuel consumption in Western Balkan countries. Reductions in information asymmetries and increases in information sharing are the channels via which transaction and travelling costs associated with CO_2 emission could be reduced through ICTs [19]. In this replication study, we are not accepting or rejecting existing theories; however, our focus is the applicability of the results found by [8]. Following [8], we investigate if there is any relation between mobile phones, Internet penetration, and CO_2 emissions in Western Balkan countries. Additionally, this empirical study differs from the existing literature which focuses on the relation between energy consumption, economic growth, and environmental pollution and the relation between energy consumption, CO_2 emission, and economic growth. Referring to [8], the existing studies in the literature do not provide adequate policy tools, as policymakers are not provided with policy instruments. In this study, ICTs are used as policy instruments. Therefore, we are investigating how improving ICTs affects CO_2 emission by establishing penetration thresholds above which CO_2 emissions can be reduced. Based on our results, we discuss policy implications.

2. Data and Methodology

In our paper, we use the data from the World Bank, World Development Indicators to study how the increasing ICT diffusion in Western Balkan countries can support the environment by lowering CO_2 emissions. The study covers the period 2000–2015 and includes six countries of the Western Balkans: Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, and Serbia. The empirical evidence is based on the Generalized Method of Moments. The following variables were used: CO_2 per capita, CO_2 from liquid fuel, mobile phones, Internet, trade, GDP growth, population growth rate, educational quality, and regulation quality. In the econometric model, both CO_2 per capita and CO_2 from liquid fuel are dependent variables. ICT is represented through the Internet and mobile phones [7,8,20–24]. Detailed variable descriptions and definitions are given in Table 1.

Table 1. Variable Definitions.

Variables	Variable Definition	Source
CO_2 per capita	CO_2 emissions (metric tons per capita)	World Development Indicators, World Bank
CO_2 from liquid fuel	CO_2 emissions from liquid fuel consumption (% of total)	World Development Indicators, World Bank
Mobile phones	Mobile phone subscriptions (per 100 people)	World Development Indicators, World Bank
Internet	Internet penetration (per 100 people)	World Development Indicators, World Bank
Trade Openness	Imports plus Exports of goods and services (% of GDP)	World Development Indicators, World Bank
GDP growth	Gross Domestic Product (GDP) growth (annual %)	World Development Indicators, World Bank
Population growth rate (annual)	Population growth rate (annual %)	World Development Indicators, World Bank
Educational quality	Pupil–teacher ratio in Primary Education	World Development Indicators, World Bank
Regulation Quality	"Regulation quality (estimate): measured as the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development"	World Development Indicators, World Bank

The macrovariables are derived from the literature that focuses on the relation between environmental pollution and economic growth. The Environmental Kuznets Curve hypothesis refers to the fact that as a country prospers, environmental pollution decreases [25]. Several studies in the literature also investigate the relation between environmental pollution and openness, population growth, and regulatory quality [26–28]. Basic education can improve economic growth and raise environmental awareness among people [29].

To understand how increasing ICT in Western Balkan countries can contribute towards environmental sustainability by decreasing CO_2 emissions, we implement the two-step GMM methodology. This method is used to overcome the problem of endogeneity between the lagged dependent variable and explanatory variables; the problem of persistency of the dependent variable. The GMM system enables both time and cross-sectional variations to be located in the model and corrects the biases inherit in the difference estimators.

There are two main econometric models conducted. In the first model, the dependent variable is CO_2 emissions (metric tons per capita), and in the second model CO_2 emissions from liquid fuel consumption (% of total). In this research paper, we used the [30], extension by [31,32]. Compared with traditional GMM, the extension is used to identify any cross-sectional dependence, controlling the number of instruments and avoiding the proliferation of instruments [7,8,33–35]. The equations presented below summarize GMM estimation in level 1 and first difference (2) as proposed by [8]:

$$CO_{i,t} = \sigma_0 + \sigma_1 CO_{i,t-1} + \sigma_2 IC_{i,t} + \sigma_3 ICIC_{i,t} + \sum_{h=1}^{5} \delta_h W_{h,i,t-1} + v_{i,t}$$

$$\begin{aligned} CO_{i,t} - CO_{i,t-1} = \sigma_1 (CO_{i,t-1} - CO_{i,t-2}) + \sigma_2 (IC_{i,t} - IC_{i,t-1}) \\ + \sigma_3 (ICIC_{i,t} - ICIC_{i,t-1}) \\ + \sum_{h=1}^{5} \delta_h (W_{h,i,t-1} - W_{h,i,t-2}) + (v_{i,t} - v_{i,t-1}) \end{aligned}$$

$$v_{i,t} = \eta_i + \xi_t + E_{i,\,t}$$

$$v_{i,t} + v_{i,t-1} = (\xi_t - \xi_{t-1}) + (E_{i,\,t} + E_{i,\,t-1})$$

In this regard, the acronyms represent the following: $CO_{i,t}$ is a CO_2 emissions indicator of country i, at period t; σ_0 is the constant term. $CO_{i,t-1}$ is the one-period-lagged CO_2 emission indicator. $IC_{i,t}$ represents information and communication technology (mobile phone penetration and Internet penetration); $ICIC_{i,t}$ represents the interaction term between $Mobile\ phone \times Mobile\ phone$ or $Internet \times Internet$; σ_1, σ_2, and σ_3, are estimated coefficients of CO_2 emission indicators, ICTs and interaction terms, respectively; ξ_t is the time-specific constant; η_i is the country-specific effects (or factors that are particular to each country in the sample), $v_{i,t}$ is the two-way disturbance term, and $\varepsilon_{i,t}$, is the error term. $W_{h,i,t-1}$ is the vector of independent variables lagged for one period (trade, GDP growth, population growth, and education and regulation quality) of country i at period $t-1$ and independent variable h with $h = 1\ldots5$; δ_h is the estimated coefficient of each independent variable.

The exogeneity of instruments used in the two-step-system GMM is crucial. The Sargent and Hansen tests of overidentification are used to determine the suitability of instruments in the model. The Sargent and Hansen overidentification tests should not be significant because the null hypotheses of these tests are that the instruments used are valid and exogenous. The Hansen test is robust but weakened by instruments. Weakened instruments refer to the inclusion of too many instruments. On the other hand, the Sargent test is not weakened by instruments, however, this test is not robust. To address this conflict, the Hansen test was chosen over Sargent, since the Hansen test prevents the proliferation of instruments. The proliferation of instruments causes overidentification. Increasing the sample size causes the number of instruments to proliferate, which leads to a bias of overfitting of the model.

Table 2 gives an overview of descriptive statistics used in the econometric models. The Jarque–Bera test of goodness-of-fit is used to measure if the skewness and kurtosis of the sample data are similar to a dataset that is normally distributed. The null hypothesis for this test is that the data is normally distributed. Therefore, with p-values being high, the null hypotheses of Internet, mobile phones, and population growth are rejected at a the, 5% level, which indicates that these variables are not normally distributed. Hence, the ordinary least square or similar techniques are not appropriate for this dataset.

Table 2. Descriptive statistics.

	CO_2 Per Capita	**CO_2 from Liquid Fuel**	**Regulation Quality**	**GDP Growth**	**Trade Openness**	**Internet**	**Mobile Phones**	**Population Growth Rate (Annual %)**	**Educational Quality**
Mean	4.097385	5934.475	0.004189	2.893829	79.97982	44.58817	93.72531	−0.627125	17.90748
Median	5.326604	4052.035	0.017169	2.718979	77.09144	48.76066	102.9265	−0.485945	17.22528
Maximum	8.101939	13,608.24	0.268441	8.290070	101.8600	67.05684	126.9370	−0.159880	22.56784
Minimum	0.978175	2845.592	−0.447581	−2.731752	63.45424	0.114097	0.952019	−1.745167	14.51830
Std. Dev.	2.490359	3106.623	0.208599	2.663266	9.821380	19.57723	31.61658	0.457031	2.210039
Skewness	−0.035115	0.785670	−0.499062	0.136732	0.366672	−1.166567	−1.870096	−1.374177	0.416461
Kurtosis	1.226343	2.340214	2.156290	2.857040	2.509551	3.575309	5.543908	3.851634	2.209825
Jarque–Bera	3.413359	3.146462	1.850441	0.103155	0.843195	6.255699	22.16555	8.968619	1.427980
Probability	0.181467	0.207374	0.396444	0.949730	0.655998	0.043812	0.000015	0.011285	0.489686
Sum	106.5320	154,296.4	0.108908	75.23954	2079.475	1159.292	2436.858	−16.30526	465.5945
Sum Sq. Dev.	155.0472	2.41×10^8	1.087837	177.3247	2411.488	9581.703	24,990.21	5.221931	122.1068
Observations	26	26	26	26	26	26	26	26	26

Table 3 shows the correlation matrix. There is a high correlation between mobile phones and the Internet, as expected. Educational quality and CO_2 per capita are inversely related; on the other hand, trade openness and CO_2 per capita are correlated positively. Although there are correlations between these variables, issues of multicollinearity are not relevant in interactive regressions [36].

Table 3. Correlations Matrix.

	CO_2 per Capita	Regulation Quality	GDP Growth	Trade Openness	Internet	Mobile Phones	Population Growth Rate (Annual %)	Educational Quality
CO_2 per capita	1							
Regulation Quality	−0.3014	1						
GDP growth	−0.3177	−0.4012	1					
Trade Openness	0.5682	0.1401	−0.3128	1				
Internet	0.2922	0.6369	−0.6292	0.6613	1			
Mobile phones	0.3889	0.5974	−0.6980	0.4426	0.8789	1		
Population growth rate (annual %)	−0.3097	0.4600	−0.1043	−0.3579	0.0759	0.18174	1	
Educational quality	−0.8660	−0.1121	0.5541	−0.7212	−0.6279	−0.6537	0.1167	1

Referring to Appendix A, all Western countries studied in this paper have high averages of CO_2 emissions from liquid fuel consumption compared with the EU average and lower penetration of both mobile and Internet on average than EU countries. Kosovo has the lowest mobile phone and Internet penetration, whereas Serbia has the highest CO_2 emissions per capita and from liquid fuel consumption among the Western Balkan Countries. Compared with the European countries, people living in the Western Balkans and Eastern Europe inhale more toxic air pollutants. In contrast to other European countries, the Western Balkans apply fewer measures to lessen air pollution. Coal-fired power plants are still widespread in the Balkans. Coal-fired power stations have generally been phased out in Western European countries [37].

3. Empirical Analysis

Empirical results are presented in Tables 4 and 5. In Table 4 the dependent variable is CO_2 emissions metric tons per capita, and two different specifications are used for this dependent variable for each explanatory variable of mobile phone and Internet. The first specification is without an interactive term, and the second specification includes an interactive term of mobile phones and the Internet with itself. Table 5 presents the results of these two different specifications of the same explanatory variables, where the dependent variable is CO_2 emission from liquid fuel consumption.

In order to assess the validity of the GMM model system, the Hansen overidentification restriction test is used to measure the validity of instruments. The Hansen test should be insignificant since the null hypothesis of the Hansen test is that the instruments are valid and they are not correlate with the error terms. Referring to the Hansen test results in Tables 4 and 5, all p-values are high, therefore it is safe to conclude that the instruments of all models are valid and are not correlated with the error terms.

Net effects can be computed using interactive specifications to measure the impact of increasing usage of ICT on CO_2 emission. For instance, using the interaction term in Table 5 column 5, the net effect of increasing Internet usage is -13.6931 (=(-0.313×44.58817) + 0.942), where 44.58817 is the mean of Internet penetration. Although the effect of Internet penetration is positive on CO_2 emission, the marginal effect of Internet penetration is negative. However, this effect is only significant at the 10% level.

Table 4. Empirical Results.

Dependent Variables: CO_2 Emissions					
CO_2 Emissions (Metric Tons Per Capita)					
Mobile					
Variable	**Coef.**	***p* Value**	**Variable**	**Coef.**	***p* Value**
CO_2 (−1)	0.91 ***	0.0000	CO_2 (−1)	0.917 ***	0.0000
GDP	2.015 ***	0.0076	GDP	0.014 ***	0.0003
Trade	−0.402 ***	0.0003	Trade	−0.154 ***	0.0057
MOBILE	0.312 **	0.0290	MOBILE	0.023	0.8728
POP	−0.167	0.2594	MOBILE * MOBILE	−0.076 *	0.0517
EDUC	−0.049 **	0.0366	POP	−0.165	0.2741
RQ	−0.545 **	0.0215	EDUC	−0.049 **	0.0414
C	1.445 ***	0.0022	RQ	−0.215 ***	0.0021
			C	1.448	0.5381
			Net Effects	NA	
R-squared	0.9725		**R-squared**	0.9616	
Adjusted R-squared	0.9612		**Adjusted R-squared**	0.9530	
AR(1)	0.801		**AR(1)**	0.079 *	
Hansen	0.431		**Hansen**	0.786	
Internet					
Variable	**Coef.**	***p* Value**	**Variable**	**Coef.**	***p* Value**
CO_2 (−1)	0.812 ***	0.0000	CO_2 (−1)	0.820 ***	0.0000
GDP	0.977 ***	0.0005	GDP	0.760 ***	0.0088
Trade	0.709 ***	0.0008	Trade	0.599 **	0.0767
POP	−0.174	0.5265	POP	−0.182	0.5235
EDUC	−0.189 *	0.0515	EDUC	−0.185 *	0.0792
INTERNET	0.746 *	0.0999	INTERNET	0.888	0.8597
RQ	−0.078 **	0.0388	INTERNET * INTRNET	−0.017 **	0.0411
C	3.223 ***	0.0000	RQ	−0.045 **	0.0644
			C	3.235 ***	0.0080
			Net Effect	NA	
R-squared	0.9724		**R-squared**	0.9725	
Adjusted R-squared	0.9633		**Adjusted R-squared**	0.9612	
AR(1)	0.019 **		**AR(1)**	0.011 **	
Hansen	0.706		**Hansen**	0.483	

Note: *, **, ***: significance levels of 10%, 5%, and 1%, respectively. NA; not applicable because at least one estimated coefficient needed for the computation of net effects is not significant. The mean of Internet penetration is 44.58817.

Table 5. Empirical results.

Dependent Variables: CO_2 Emissions					
CO_2 Emissions from Liquid Fuel Consumption (% of Total)					
Mobile					
Variable	**Coef.**	***p* Value**	**Variable**	**Coef.**	***p* Value**
CO_2 (−1)	0.836 ***	0.0000	CO_2 (−1)	0.833 ***	0.0000
GDP	8.614 ***	0.0017	GDP	6.550 ***	0.0003
Trade	−7.733 **	0.0338	Trade	−9.637 ***	0.0002
POP	0.618	0.1409	POP	0.446	0.1750
EDUC	4.968	0.2701	EDUC	0.006	0.2785
MOBILE	0.042	0.3329	MOBILE	0.081	0.7416
RQ	−0.215 **	0.0214	RQ	−0.165 *	0.0547
C	2.516 ***	0.0028	MOBILE * MOBILE	−0.072 *	0.5302
			C	6.108 **	0.0384
			Net Effect	NA	
R-squared	0.9750		**R-squared**	0.9753	
Adjusted R-squared	0.9703		**Adjusted R-squared**	0.9698	
AR(1)	0.0125 **		**AR(1)**	0.0000 ***	
Hansen	0.7858		**Hansen**	0.6084	
Internet					
Variable	**Coef.**	***p* Value**	**Variable**	**Coef.**	***p* Value**
CO_2 (−1)	0.709 ***	0.0000	CO_2 (−1)	0.745 ***	0.0000
GDP	2.935 ***	0.0018	GDP	3.191 ***	0.0007
Trade	0.969 ***	0.0066	Trade	6.980 ***	0.0011
POP	0.520	0.1754	POP	0.107	0.4402
EDUC	1.326	0.1295	EDUC	0.199	0.2213
INTERNET	0.263 *	0.0508	INTERNET	0.942 *	0.0949
RQ	−0.051 **	0.0359	INTRNET * INTERNET	−0.313 ***	0.0084
C	4.391 ***	0.0007	RQ	−0.025 **	0.0248
			C	6.318 ***	0.0086
			Net Effect	−13.6931	
R-squared	0.9759		**R-squared**	0.9769	
Adjusted R-squared	0.9679		**Adjusted R-squared**	0.9674	
AR(1)	0.0000 ***		**AR(1)**	0.031 **	
Hansen	0.8782		**Hansen**	0.2765	

Note: *, **, ***: significance levels of 10%, 5%, and 1%, respectively. NA: not applicable because at least one estimated coefficient needed for the computation of net effects is not significant. The mean of Internet penetration is 44.58817.

Referring to Table 4, ICTs—mobile phones and Internet—are significant and positive at the 5% and 10% level, respectively, in the noninteractive specification; therefore, especially an increase in mobile phones alone increases the CO_2 emission per capita. Referring to Table 5, mobile phone penetration alone is not significant and does not have a significant effect on CO_2 emissions from liquid fuel consumption. The coefficient of Internet penetration is significant at the 10% level as far as CO_2 emissions from liquid fluid consumption is concerned. Regarding the interactive regressions, increasing ICTs has a negative net effect on per capita CO_2 emissions per capita and from liquid fluid consumption. This impact is limited when mobile phone penetration is considered, since the interactive terms are significant only at the 10% level. The values of all estimated lagged dependent variables are between zero and one in absolute terms, suggesting that past values of CO_2 emissions have a positive impact on future values of CO_2 emission.

Institutional quality is measured by regulation quality and other human factors are measured by educational quality. It is expected that quality of education and regulation quality negatively affect CO_2 emissions. Both control variables have negative and significant coefficients in Table 4. For Internet penetration, regulation quality is negative and significant at the 5% level and education quality is significant at the 10% level. Referring to CO_2 emissions from liquid fuel consumption, education quality is not significant and the sign is not as expected, whereas regulation quality is both negative and significant for all specifications and ICTs used in this paper. GDP growth and population are used to measure the impact of the market and trade openness is used to measure the impact of globalization on CO_2 emissions. GDP growth is positive and significant on both tables. This reflects that growing GDP contributes to environmental damages. Trade openness and population are expected to have positive signs. In most specifications, trade openness has signs as expected. Population is insignificant for all specifications and ICTs.

The results indicate that an increase in ICTs increases CO_2 emissions, although in some specifications the signs of the coefficients are not significant. Luckily, all marginal effects are negative, implying that increasing ICT has a decreasing impact on CO_2 emissions. The marginal effects for mobile phone penetration are significant at the 10% level for both CO_2 emissions per capita and from liquid fuel consumption. These marginal effects can be crucial, since at certain thresholds the net impact could be changed from positive to negative. Here, the threshold refers to the point at which further employment of ICTs results in a net negative impact on CO_2 emissions. Therefore, policymakers, by increasing ICT penetration beyond these thresholds, can achieve the desired environmental sustainability if these thresholds are within the statistical range. The calculated threshold for CO_2 emissions from liquid fuel consumption is 3.0 (=0.942/0.313) for Internet penetration. This number is within the statistical range of Internet penetration since Internet penetration range is between 0.114097 and 67.0584 per 100 people. However, this threshold is below the mean Internet penetration of the entire sample, so it can be used as a policy tool by the countries in the sample that have a mean penetration level below 3.0 per 100 people. Although this threshold has limited usage as a policy tool, it means that increasing the Internet penetration above 3.0 per 100 people would reduce CO_2 emissions from liquid fuel consumption and may improve environmental sustainability.

4. Conclusions

In this study, we examined the impact of increasing ICT penetration in six countries of the Western Balkans: Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, and Serbia for the period of 2000–2015. The empirical evidence is based on the Generalized Method of Moments. Mobile phone and Internet penetrations are used to measure the impact of ICTs on CO_2 emissions per capita and CO_2 emissions from liquid fuel consumption, which are proxies for CO_2 emission. Our results indicate that Internet penetration increases CO_2 emissions, however, it is only significant at the 10% level when CO_2 emissions from liquid fuel consumption is used as a dependent variable in noninteractive models. Mobile penetration increases CO_2 emissions per capita, but it does not significantly affect CO_2 emission from liquid fuel consumption. From the noninteractive regressions, we find out that increasing ICT penetration of both mobile phones and the Internet would not significantly affect CO_2 emission from liquid fuel consumption. However, these results are contradictory as far as CO_2 emissions per capita and mobile phone penetration are concerned. Using interactive terms, all marginal effects are negative. As far as CO_2 emission from liquid fuel consumption is concerned, an increase in Internet penetration has a negative net impact on CO_2 emissions.

We calculated net effects where both estimated coefficients needed for the computation of net effects are significant at least at the 10% level. We also computed the corresponding threshold and found that the threshold for Internet penetration is 3.0 per 100 people. While this threshold is within the practical range, it has no practical implication for policy, since the mean Internet penetration in the sample is around 44 per 100 people. The countries which have low mean Internet penetration level may consider increasing their penetration above 3.0 per 100 people. This main policy implication of our findings could be helpful especially for Kosovar policymakers, since the mean penetration is 0.104, which is way below the threshold of 3.0 per 100 people. Kosovar policymakers can address the issues related to Internet penetration such as affordability and lack of infrastructures. Policies such as low-price Internet and broad coverage could be considered to increase the Internet penetration levels to enhance environmental sustainability.

Our results also indicate that Internet penetration could be strengthened to reduce CO_2 emission both per capita and from liquid fuel consumption. Consolidating Internet penetration is appealing because the Internet is widely used on many devices including cell phones, computers, and so on. Therefore, increasing Internet penetration is more applicable than for mobile phones, although the Internet and mobile phones complements each other. In this regard, policymakers could take advantage of our findings as Western Balkan countries are in the process of adopting legal framework and strategies to reduce the release from coal plants by addressing issues related to Internet penetration related to affordability and lack of coverage. To reduce CO_2 emissions both per capita and for liquid fuel consumption, Internet penetration policies such as access and acquisition could be tailored specifically to individual country needs. As we also mentioned in the introduction, the majority of Western Balkan countries breached the NERP pollution limits. Thus, policymakers could adopt interdisciplinary policies and strategies in Western Balkan countries, especially in Kosovo, to handle the breaches of the NERP pollution limits in 2018 and 2019 [17].

Mitigation of CO_2 emission through the importance of ICT is consistent with the existing literature. ICT penetration decreases cost/traffic per minute in relation to economic operations. For example, physical meetings could be replaced by a virtual meeting through a mobile phone with Internet; therefore, the number of physical meetings could be reduced as the transportation costs and associated CO_2 emissions are reduced. Additionally, the importance of ICT could increase in the future as the energy policies of the world have been changing due to political and regional conflicts arising from the production of oil and natural gas and global warming. Additionally, the effects of ICT on CO_2 emissions could be increased in the future due to availability of more data.

There are limitations to this study. First, the sample size is small due to missing values. This study could be revised in the future when there are more data available for the countries in the sample. Second, the impact of ICT could be country specific. Country-specific effects are eliminated to limit the endogeneity between the lagged endogenous variable and the error term. All Balkan countries are treated as a homogeneous group, and it is assumed that the results are all applicable to all countries in the sample. A future study could be conducted by employing different estimation techniques which could handle the impact of country-specific effects and compare the results of this existing study.

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Appendix A

Table A1. Comparison of Western Countries with EU averages.

Country	Statistics	CO_2 Emissions (Metric Tons per Capita)	CO_2 Emissions from Liquid Fuel Consumption (% of Total)	Mobile Cellular Subscriptions (per 100 People)	Individuals Using the Internet (% of Population)
Albania	*Mean*	1.459219	3518.487	70.48267	26.82382
	Standard Deviation	0.2538902	312.9765	40.49354	25.05269
Bosnia and Herzegovina	*Mean*	4.951724	3736.215	62.03168	28.36726
	Standard Deviation	0.9854235	546.0209	34.2182	18.75791
Kosovo	*Mean*	5.936943	1692.932	32.3021	0.0913333
	Standard Deviation	0.4251391	139.9558	11.23467	0.0197248
Montenegro	*Mean*	3.528987	777.7374	158.5412	43.10726
	Standard Deviation	0.3922508	185.888	35.85418	15.15168
North Macedonia	*Mean*	4.745985	2708.079	71.61637	39.10649
	Standard Deviation	0.8117569	175.0457	37.65919	22.35685
Serbia	*Mean*	6.645	10,168.96	101.8913	44.60925
	Standard Deviation	0.9306903	2293.108	11.73191	12.47982
European Union	*Mean*	**7.468982**	**41.74356**	**102.2405**	**54.98243**
	Standard Deviation	0.5967262	1.605777	25.27747	18.60451

Table A2. The Policy Tool Selection and Implementation Risk.

Variables	Possible Results	Policy Tool Selection	Policy Recommendations	Implementation Risks
Internet penetration (per 100 people)	An increase in Internet penetration does not increase CO_2 emissions per capita and decreases CO_2 from liquid fuel consumption. An increase in Internet penetration above the threshold for the countries where the Internet penetration is below the sample mean.	Internet Penetration	Policymakers can solve issues associated with affordability and lack of coverage.	The infrastructure and the income of the countries in the sample.

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