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Article

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Can Digital Human Capital Mitigate CO2 Emissions? Empirical Test for Post-Communist Countries

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ABSTRACT

This study investigates the relationship between internet users, a proxy for digital human capital, and CO_2 emissions in a sample of Post-Communist countries over the period 1990-2019. The results suggest that internet diffusion is negatively and significantly correlated with CO_2 emission even after controlling for other economic antecedents of environmental degradation. Moreover, using fixed effects two-stage least squares estimator, we document that internet has causal impact on carbon emissions. In the full specification, a 10 percentage points increase in internet use leads to 4.2% decrease in CO_2 emissions across Post-Communist countries. These results remain intact even when we introduce additional control variables in the model and conduct analysis on sub-samples. The papers highlights that human capital leads to sustainable development in developing countries.

Keywords: ICT, Internet, Carbon emissions, Post-Communist
JEL Classifications: Q5

1. INTRODUCTION

Carbon emissions is one of the most important global problems and have negative implications for the society. As suggested by WHO 4.2 million people die annually due to the health impacts of air pollution. Empirical studies report that carbon emissions increase infant mortality (Currie and Neidell, 2005), decrease life expectancy (Murthy et al., 2021) and life satisfaction (Ferreira et al., 2013).

Present study aims to explore the effect of Internet on CO_2 emissions across Post-Communist countries. Internet play a crucial role in the technological advance, but albeit the internet usage has substantially increased over the past decade, its diffusion remains to be significantly uneven. For example, in 2018 only approximately 75% of population in former communist countries had access to Internet compared to 82% in OECD countries or 83% in Euro Area nations. Internet as one of the dimensions of digital revolution is an important catalyst for the development of society as it carries numerous hopes for the developing economies, enabling them to jump across the levels of development and reach developed nations. At the same time in emerging and transition economies, ICT infrastructure quality has been underdevelopment and the policymakers tend to place lower priorities compared to industries on the development agenda. For example, ICT investment in Russia is forecast to reach 1.4% of GDP[1] compared to 3.5% in Switzerland or 2.3% in UK. Consequently, the ICT penetration in developing countries is relatively low and the speed of Internet relative to its cost is better in developed countries.

Cross-country studies suggest that Internet is essential for social and economic progress and quality of life. For example, Canh et al. (2020) using data for 87 nations over the period 2002-2014

1 https://store.globaldata.com/report/kg0220ci--ict-investment-trends-in-russia-enterprise-ict-spending-patterns-through-to-the-end-of-2017/

reports that internet diffusion is an important tool to decrease income inequality. Moreover, the scholars estimate that digital economy accounts for the 15.5% of global output (Huawei and Oxford Economics, 2017). Considering that some of the economic activities are now in the ICT sector, these shifts may influence energy consumption influencing carbon emissions. While economics growth/development and energy consumption are among two crucial variables that explain significant variations in carbon emissions, there is evidence that Internet diffusion may have direct and indirect effects on CO_2 emissions. For example, a number of studies show that ICT sector development has impact on the energy consumption across countries. Salahuddin and Alam (2016) document that a 10 percent rise in Internet diffusion leads to nearly 0.3% rise in electricity consumption across OECD nations in the long run. Furthermore, Sadorsky (2012) finds that a 10% increase in Internet penetration leads to an increase in 0.11% in per person electricity consumption. On the other hand, a number of studies report that Internet diffusion decreases energy consumption (Schulte et al., 2016). For instance, Pelau and Acatrinei (2019), using data from 29 nations in Europe for the years 2010-2016, find that energy consumption decreases when countries make a transformation to a digital society. Therefore, the results for the link between Internet usage and energy (electricity) consumption are mixed and require further investigations. Overall, there a number of reasons how Internet usage may influence CO_2 emissions via energy consumption channel. First, Internet sector may reduce demand for energy by improving efficiency and sectoral transformations. Second, digitalization may lead to greater energy demand, and, consequently, to rise in CO_2 emissions due to ICT sector growth, energy rebound effects and rapid economic growth (Lange et al., 2020).

Indeed, the large strand of existing research explores the effect of Internet on CO_2 emissions along with economic growth (Lee and Brahmasrene, 2014; Al-Mulali et al., 2015; Salahuddin et al., 2016a) and energy consumption (Gelenbe and Caseau, 2015; Lu, 2018). For example, Ozcan and Apergis (2018), using data for 20 emerging countries over the period 1990-2015, investigate the effect of Internet diffusion on CO_2 emissions. The study reports that Internet usage has negative effect on carbon emissions and confirms that causality runs from ICT to environment. Salahuddin et al. (2016b) explores the role that Internet usage plays in explaining changes on carbon dioxide emissions in Australia over the years 1985-2012. The authors relying on Autoregressive distributive lag (ARDL) bounds fail to find evidence on the significant link between ICT and CO_2 emissions in the short run, however, impulse response and variance decomposition analysis show that Internet will have impact on CO_2 emissions in the long-run. On the other hand, Park et al. (2018) finds that Internet has positive and causal long run effect on CO_2 emissions in selected EU countries accounting for the role of financial development, GDP growth and trade openness. One of the potential explanations the authors propose is that ICT development increases the demand for energy use which has in turn effect on carbon emissions. Awan et al. (2022) investigates the link between renewable energy, ICT use, FDI and CO_2 emissions in a sample of 10 emerging countries over the years 1996-2015, using Method of Moments Quantile regression estimator. The empirical findings confirm the evidence on non-linear relationship between GDP and environmental degradation. Urbanization increases CO_2 emissions, while renewable energy and Internet penetration mitigates environmental degradation. Liu et al. (2023) explore the drivers of climate change in Belt and Road Initiative countries over the period 2008-2020. The authors apply a large set of empirical methods such as unit root tests, Granger causality tests, AMG and PMG estimators. The study among others shows that energy intensity and Internet use are positively linked to CO_2 emissions. Renewable energy and economic development is inversely linked to environmental degradation. Altinoz et al. (2021) assess the nexus between ICT use, TFP and CO_2 emissions over the period 1995-2014 using the panel vector autocorrection model. The empirical results suggest that some dimension of digital human capital increase CO_2 emissions such as Internet users and fixed phone users, while mobile usage reduces CO_2 emissions.

However, to the best of our knowledge, no research has been carried out in the Post-Communist countries. In addition, extant research offers inconclusive empirical evidence on the effect of Internet diffusion on CO_2 emissions and, hence, may not be interpolated for former communist countries. Thus, ours is the first study to robustly empirically assess the relationship between Internet and carbon emissions for this group of countries for the period 1990-2019. Our study contributes to extant research in a number of ways. First, we focus on a specific group of countries that have common cultural and political heritage. As a result, our baseline results should not be significantly affected by heterogeneity in political experience that may exist in cross-country studies. Second, based on Carbon Atlas the carbon emissions in Post-Communist countries have decreased by approximately 32% since 1990. At the same time, according to World Bank Internet usage has increased from <1% in early 1990s to nearly 75% of population. Third, from the empirical viewpoint, we enhance the framework of Ahmed et al. (2019) to explore the effect ICT on air pollution. Compared to other panel studies, we rely on a wide range of empirical strategies and robustness checks. We also assess the causal effect of Internet diffusion on CO_2 emissions in this region.

Our results suggest that Internet usage is significantly and negatively linked to carbon emissions even after accounting for mediating channels such as energy use and economic growth. Moreover, our empirical results show that Internet has causal negative effect on CO_2 emissions in Post-Communist countries. In particular, a 10 percentage points increase in Internet diffusion leads to 4.2% decrease in CO_2 emissions.

2. MODEL, METHODOLOGY AND DATA

In this study we depart from the STRIPAT (Stochastic Impacts by regression on population, affluence and technology) framework to explore the relationship between internet and carbon emissions. The conventional specification of the model is:

$$I_i = \alpha P_i^{\beta} A_i^{c} T_i^{d} \varepsilon_i \quad (1)$$

where I is for CO_2 emissions; P denotes population, A is for affluence, T represents technology. We use urbanization as a proxy for population, and GDP per capita is as our measure of affluence. Following, Xu and Lin (2015) and Ahmed et al. (2019) we include energy use to produce GDP in our model. Internet usage, measured by percentage of population using internet, is used to capture the role of ICT technology. In addition, as suggested by Shahbaz et al. (2016) we include trade openness (exports + imports as a share of GDP) to capture the role of global interdependencies play in environmental degradation. As a result, we use the modified STRIPAT model in its linear form which can be expressed as:

$$CO2_{i,t} = \alpha_0 + a_1 Internet_{i,t} + a_2 GDP_{i,t} + a_3 Urban_{i,t} + a_4 Trade_{i,t} + a_5 Energy_{i,t} + \varepsilon_{i,t} \quad (2)$$

where CO_2 is CO_2 emissions per capita, Internet is individuals using the Internet (% of population), GDP is GDP per capita adjusted for purchasing power parity, Urban is share of urban population, Trade is the sum of exports and imports as % of GDP and Energy is energy use (kg of oil equivalent) per $1,000 GDP (constant 2017 PPP).

Our study uses data covering years 1990-2019. The data on carbon emissions comes from Carbon Atlas. The data on GDP per capita, urbanization, trade and energy intensity are obtained from World Bank. The descriptive statistics are reported in Table 1.

While the goal of this study is to completely take advantage of the panel data that exists for Post-Communist nations, we first start from estimating Eq. (1) using conventional ordinary least squares (OLS) regression estimator. Next, we proceed with fixed effects and random effects methods – a standard approach in panel data econometrics. The fixed effects (FE) method enables the researchers to take into account unobserved country specific time-invariant heterogeneity which leads to omitted variable bias (Adams, 2009). The random effects (RE) model also useful to assess the overall robustness of our main findings when deviations across sub-groups are random from a parent group. We also adopt panel corrected standard errors (PCSE) estimator as the data in our study may be induced by simultaneous correlation across panel and heteroskedasticity. Consequently, fixed effects or random effects results may generate inefficient estimates. In order to confirm the strength of our findings we re-estimate Eq. (1) using PCSE.

On the other hand, the effect of Internet on CO_2 emissions may not be endogenous or it could be that air polluting nations may be relying on outdated technologies or rely on economic sectors that hamper ICT development. Therefore, following the work of Lapatinas (2019) we adopt fixed effects instrumental variable two-state least squares (FE IV 2SLS) regression model strategy. We use logged number of secure internet servers per million population from World Bank and civil liberties index from Freedom house.

3. EMPIRICAL RESULTS

The baseline results are reported in Table 2. Column 2 presents the results from estimating Eq. (2) using conventional OLS regression. The coefficient for Internet is negative statistically significant, suggesting that internet usage is negatively correlated with carbon emissions across Post-Communist countries. Turning to our control variables we find that urbanization, GDP and energy intensity are positively linked to CO_2 emissions in our sample. These results are similar to the findings reported by Qi et al. (2020) for China and Chen et al. (2020) for MERCOSUR nations. Trade openness seems to be insignificant correlated of carbon emissions in our sample. Column 2 re-visits our primary results using fixed effects regression estimator. The coefficients suggest that the estimates for Internet usage and control variables are not quantitatively and qualitatively affected once we consider for the role that unobserved time-invariant country characteristics may play in predicting environmental degradation. For example, a 10% percentage points increase in internet usage is associated with 5.8% decrease in CO_2 emissions. In column 3, we adopt random effects regression model to estimate Eq. (2). Again, the results are nearly identical to our baseline results in Columns 1 and 2. Therefore, the findings in Table 2 suggest that Internet usage is negatively and significantly associated with CO_2 emissions across Post-Communist countries.

In Table 3, we attempt to overcome the limitations of the conventional estimators adopted in panel data empirical analysis. Column 1 reports the results from estimating PCSE estimator. The coefficient is negative and statistically significant. The signs and values of control variables are similar to the ones reported in Table 2. We proceed assessing the causal effect of Internet usage on CO_2 emissions in Column 2. As discussed above we rely on FE IV 2SLS strategy. The 2nd stage results confirm that Internet is negative and statistically significant. This suggests that Internet may have causal impact on CO_2 emissions. If causal, a 10 percentage points increase in Internet use leads to 4.2% decrease in CO_2 emissions across Post-Communist countries. The results from the 1st stage suggest that only secure internet servers is positive and significant. The F-stat from the 1st stage is above the threshold level of 10 suggesting that our instruments are overall valid and credible.

In Table 4, to check robustness of our main results we extend our model by incorporating additional variables as suggested by extant cross-country studies. Following, Yang et al. (2020) we account for the role of globalization in explaining CO_2 emissions by including

Table 1: Descriptive statistics

Variable	Description	Mean	SD
CO_2 emissions	Territorial emissions in tCO□ per person	6.05	3.86
GDP	GDP per capita, PPP (constant 2017 international $)	15,022.83	9116.44
Internet	Individuals using the internet (percentage of population)	29.20	28.49
Urban	Urban population (percentage of total population)	57.51	11.92
Trade	Trade (percentage of GDP)	97.89	33.18
Energy	Energy use (kg of oil equivalent) per $1000 GDP (constant 2017 PPP)	221.40	153.17

SD: Standard deviation, PPP: Purchasing power parity, CO_2: Carbon dioxide

Table 2: Main results

Variable	I	II	III
Internet	−0.0060 (7.67)***	−0.0058 (5.78)***	−0.0056 (6.09)***
Urban	0.0030 (2.22)**	0.0422 (2.91)***	0.0293 (3.49)***
GDP	1.2906 (47.13)***	1.0402 (9.21)***	1.0346 (9.28)***
Trade	−0.0002 (0.47)	−0.0004 (0.74)	−0.0004 (0.66)
Energy	0.0041 (27.25)***	0.0032 (6.81)***	0.0031 (6.54)***
Constant	−11.4180 (48.07)***	−11.1417 (7.77)***	−10.3250 (9.29)***
R^2	0.87	0.70	0.70
N	521	521	521
Method	OLS	RE	FE

*P<0.1, **P<0.05, ***P<0.01. OLS: Ordinary least square, FE: Fixed effect, RE: Random effect

Table 3: IV 2SLS and PCSE

Variable	I	II	III
Internet	−0.0054 (8.22)***	−0.0042 (2.27)**	
Urban	0.0043 (3.08)***	−0.0108 (0.47)	1.1646 (0.74)
GDP	1.2156 (35.34)***	1.2473 (6.42)***	9.3554 (0.70)
Trade	−0.0004 (1.19)	−0.0037 (4.73)***	−0.1491 (2.49)**
Energy	0.0038 (20.57)***	0.0034 (5.75)***	0.0015 (0.04)
Servers			7.4939 (7.04)***
Civil liberties			2.0549 (0.84)
Constant	−10.7033 (34.29)***	−9.7895 (4.04)***	−128.9399 (0.79)
R^2	0.87	0.82	0.61
1st stage F-statistics			33.88
N	521	130	130
Notes	PCSE	FE IV 2SLS 2nd stage	FE IV 2SLS 1st stage

*P<0.1, **P<0.05, ***P<0.01. FE IV 2SLS: Fixed effects instrumental variable two-state least square, PCSE: Panel corrected standard error

Table 4: Robustness test

Variable	I	II	III
Internet	−0.0059 (2.51)**	−0.0034 (3.38)***	−0.0036 (4.96)***
Urban	−0.0198 (0.98)	0.0364 (2.27)**	0.0029 (1.61)
GDP	1.1846 (7.06)***	0.9361 (5.71)***	1.1128 (22.71)***
Trade	−0.0044 (4.92)***	0.0000 (0.06)	−0.0000 (0.08)
Energy	0.0027 (4.75)***	0.0025 (4.57)***	0.0033 (17.45)***
Freedom	−0.0085 (1.42)	−0.0035 (1.09)	−0.0001 (0.10)
Globalization	0.0201 (2.07)**	−0.0050 (1.06)	−0.0032 (1.55)
FDI	0.0012 (0.60)	0.0026 (1.85)*	0.0004 (0.54)
Renewable	−0.0059 (5.03)***	−0.0044 (2.07)**	−0.0042 (5.66)***
Constant	−9.1343 (4.11)***	−9.1885 (4.91)***	−9.3439 (20.83)***
N	130	464	464
R^2	0.76	0.59	0.85
Method	FE IV 2SLS	FE	PCSE

*P<0.1, **P<0.05, ***P<0.01. FE IV 2SLS: Fixed effects instrumental variable two-state least square, PCSE: Panel corrected standard error, FE: Fixed effect, FDI: Foreign direct investment

Table 5: Sub-samples

Variable	I	II	III
Internet	−0.0046 (4.32)***	−0.0058 (5.25)***	−0.0049 (6.01)***
Urban	0.0208 (1.10)	0.0592 (3.18)***	0.0305 (2.99)***
GDP	0.9537 (6.73)***	1.0302 (9.99)***	1.1163 (10.41)***
Trade	0.0001 (0.10)	0.0002 (0.31)	−0.0008 (1.38)
Energy	0.0024 (4.92)***	0.0034 (8.34)***	0.0041 (11.30)***
Constant	−9.0254 (4.63)***	−12.1619 (8.55)***	−11.3562 (9.19)***
R^2	0.55	0.76	0.77
N	357	386	472
Notes	2000–2019	1990–2010	Excluding outliers

*P<0.1, **P<0.05, ***P<0.01

KOF Index of Globalization. In order to capture the effect of economic institutions on carbon emissions, we include Economic freedom index from Heritage Foundation. In addition, a number of studies suggest that renewable energy sector development and FDI may serve as antecedents of CO_2 emissions in cross-country research (Naz et al., 2019). Therefore, we include renewable electricity output as % of total electricity output and FDI as % of GDP from World Bank. Of these variables, only renewable energy production is robustly and negatively associated with CO_2 emissions. Turning to our main variable of interest, Internet diffusion is negative and statistically significant.

Finally, we test whether our results are sensitive to the choice of data points. Therefore, we re-estimate Eq. (1) for various sub-samples in Table 5. First, we restrict our time period only for 2000-2019. Post-Communist countries were associated with instable economic growth and transition shocks at early 1990's. Moreover, the Internet penetration levels were relatively low until the early 2000's across countries in this region. Therefore, this may impact our main results. In column 2, we restrict our time period for the years 1990-2010 to reduce the effect of various external shocks that had effect on the development of these countries. Finally, in column 3 we remove influential data points that were reported by regression post-estimation plots, namely Tajikistan, Uzbekistan and Turkmenistan. Across all columns the coefficient for internet is negative and significant.

4. CONCLUSION

The main goal of this study is to assess the effect of Internet diffusion on carbon dioxide emissions in a sample of Post-Communist countries. In the first step, we have used conventional methods such as OLS, RE and FE to assess the baseline findings. In the next step, we resorted on more sophisticated empirical strategy to account for cross-sectional dependence among panels and causality between ICT and CO_2 emissions. Thus, the study applied fixed effects instrumental variable regression estimator to assess the direction of causality. In this study, following Lapatinas (2019) we used the number of secure internet servers (per 1 million people) and civil liberties index as our instruments for Internet diffusion.

The main results in this study are as follows. The FE and RE regressions confirm that Internet usage is negatively and significantly correlated with CO_2 emission even after controlling for other economic antecedents of environmental degradation. The FE IV 2SLS coefficients suggest that Internet is has causal effect on CO_2 emissions in the region. In the full specification, a 10 percentage points increase in Internet use leads to 4.2% decrease in CO_2 emissions across Post-Communist countries. These results remain intact even when we introduce additional control variables in the model and conduct analysis on sub-samples.

Based on the empirical results of our study, following policy implications can be derived for countries in this region. First, Internet diffusion seems to play important role in curbing air pollution in our sample. Therefore, further investments in the ICT sector should also have non-economic benefits for the society. Our results contribute to the findings that ICT sector enhances economic growth (Mičetić and Vlahinić-Dizdarević, 2006) and innovative activities in transition countries (Gërguri□Rashiti et al., 2017). Second, we also document renewable energy sector is also robustly linked to reduction in CO_2 emissions in our analysis. Therefore, policy makers can resort to a number of fiscal and economic incentives such as tax reduction, investment grants, low interest loans and grants to motivate companies invest in ICT and renewable energy sectors. A number of studies from this region suggest that investment in human capital is instrumental to foster renewable energy adoption (Eshchanov et al., 2021). Third, our findings suggest that energy intensity has significant positive effect on CO_2 emissions. Therefore, it is crucial to adopt energy efficient technologies to reduce the rising pressure of energy use in these countries on the environmental quality.

Prospective studies should explore the role that other economic variables (finance, trade, FDI) may play in explaining carbon emissions in this region. In addition, our results could be extended by exploring the link between ICT and CO_2 emissions using sub-national data from these countries.

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