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# The Impact of Digital Economy and Renewable Energy Consumption on the Energy Poverty in V4 Countries

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**Abstract**

To effectively address energy poverty in the European Union, energy policies must be designed to integrate the digital transformation and renewable energy. This means that the entire EU policy framework should be treated as an interconnected system. The aim of this paper is to analyse the impact of Internet development and renewable energy consumption on energy poverty in the V4 countries in the period 2005-2023. The results based on Pesaran & Smith (1995) Mean Group estimators suggested that Internet use, Internet access and Internet frequency enhanced energy poverty, while renewable energy consumption enhanced it. Moreover, unemployment increased energy poverty, FDI reduced the population unable to keep home adequately warm and increased the arrears on utility bills, while poverty had a direct impact on population unable to maintain home warm. These empirical results should consider revisions in the energy policy to tackle both energy poverty and the necessity to increase the renewable energy consumption.

**Keywords:** energy poverty, renewable energy consumption, Internet
**Jel codes:** C51, C53

## 1. Introduction

The energy poverty, lately accelerated by higher energy prices and living costs, has become a major challenge for the EU energy policy and its negative effects are threats for individuals and public health, wealth and energy security. The percentage of EU citizens unable to keep the homes warm enough in the total population has increased from 8% in 2020 to 9.3% in 2022 (European Commission, 2023). Given the necessity to urgently address this issue, the Commission has recommended in October 2023 more investment in renewable energy and energy issue. However, besides the utility of these proposals, the European Commission needs to move the research forward. First, it should consider the interaction between energy policy and other actual policies, like digital policy focused on digital transformation. Second, empirical studies should be conducted to prove on a statistical basis if renewable energy reduces, indeed, the energy poverty. In developing countries, the high costs of renewable energy might enhance energy poverty and, in this case, more governmental support is necessary. It is commonly accepted in literature that digital tools and data have the potential to play a significant role in reducing energy poverty, but empirical studies are necessary to support this hypothesis for various groups of countries like V4 countries (Hungary, Slovakia, Poland and Czech Republic).

Digital technologies offer promising solutions to address energy poverty by enhancing targeting and efficiency. By employing digital tools to identify households most vulnerable to energy insecurity, policymakers can implement tailored interventions and allocate resources effectively. Smart energy monitoring systems provide real-time data on household consumption, enabling personalized recommendations for energy conservation and efficient appliance usage. Additionally, digital platforms can streamline financial aid programs by facilitating needs assessments and benefit disbursement, ensuring that resources reach those in greatest need (Varo et al., 2022).

Digital solutions also have the potential to empower communities. Online platforms can disseminate information about energy-saving tips, government programs, and financial assistance opportunities, empowering individuals to make informed decisions about their energy usage. Social media groups and online communities can foster peer-to-peer learning and support, facilitating the exchange of best practices and experiences related to energy conservation and efficient habits. Moreover, online platforms can provide information and connect individuals with opportunities to invest in or adopt renewable energy solutions, such as solar panels (Luan et al., 2023). Despite these advantages, it is crucial to acknowledge the potential limitations of digital solutions. The digital divide, characterized by unequal access to technology and internet connectivity, can exacerbate existing inequalities and limit the reach of digital solutions to the most vulnerable communities. Data privacy and security concerns arise from the sharing of personal energy consumption data, necessitating robust data protection measures and responsible information handling. Furthermore, the affordability of technological solutions may pose a barrier for low-income communities, requiring additional interventions to address affordability challenges (Wang et al., 2023).

By examining the interplay between digital development, renewable energy consumption, and energy poverty in this zone, this research aims to provide valuable insights for developing effective policies that address these interconnected challenges. While many studies have linked various digital economy indexes to energy poverty, few have utilized Internet development as a proxy for digital economy in this context. Consequently, the primary objective of this paper is to assess the impact of Internet development on energy poverty in V4 countries, considering the potential role of renewable energy consumption in mitigating this issue. A panel data analysis of macroeconomic indicators suggests that increased internet usage is associated with decreased energy poverty, while higher renewable energy consumption may exacerbate it.

## 2. Literature Review

While the fundamental concept of energy poverty is widely understood, researchers have yet to agree on a single, universally accepted definition. The definitions presented in the literature reflect diverse perspectives. For instance, the World Economic Forum defines energy poverty as the absence of access to sustainable modern energy services and products. This definition underscores the sustainability aspect, emphasizing the environmental implications of energy choices (Awan et al., 2013). The European Commission (2020) views energy poverty as a situation where households "are unable to access essential energy services," including adequate heating, cooling, lighting, and power for appliances. This definition centers on household access and the specific energy services required for basic needs.

Expanding on this, some researchers broaden the definition to encompass not only the lack of access but also the affordability, reliability, quality, safety, and environmental soundness of energy services. This comprehensive approach acknowledges the multifaceted nature of energy poverty. Inspired by the IEA's energy development index, Nussbaumer et al. (2012) developed a multidimensional energy poverty index (MEPI). This index goes beyond measuring simple energy access. It incorporates various dimensions, including economic and social aspects, extending beyond mere accessibility, affordability, and basic energy needs. In essence, the MEPI captures energy poverty as a state of deprivation in terms of obtaining and utilizing modern energy services. Pachauri and Spreng (2011) identified three primary methods for quantifying energy poverty: physical, technological, and economic thresholds. Each approach offers valuable insights, but also has limitations.

The physical threshold approach, aligned with the World Bank's absolute poverty framework, defines a minimum energy consumption level required for basic needs. However, accurately measuring such consumption for specific necessities can be challenging due to data scarcity. Additionally, determining a universally "adequate temperature" across diverse climates can be subjective (Pelz et al., 2018).

The technological threshold approach focuses on the lack of access to essential energy services like electricity and clean cooking facilities. While valuable, it overlooks the affordability aspect, potentially excluding households unable to afford these services despite having access (Nussbaumer et al., 2012).

The economic threshold approach defines a maximum income percentage allocated to energy expenditure as representing an acceptable standard. However, this approach fails to account for varying energy prices and purchasing power across different regions, potentially misrepresenting the true extent of energy poverty (Herrero, 2017).

These limitations highlight the need for comprehensive approaches to measuring energy poverty. Such approaches should encompass not just access, but also affordability, consumption patterns, and the contextual factors influencing them.

Empirical evidence suggests a significant impact of the digital economy on energy poverty. For example, a study of 30 Chinese provinces revealed regional disparities and a mediating effect of financial development: digital economy significantly reduced energy poverty in eastern and western provinces, while central provinces reported no significant effect during the period 2011-2019 (Qu and Hao, 2021). For the same period, Zhang et al. (2023) identified a significant, nonlinear, and heterogeneous effect of Internet development on energy affordability. Additionally, Postuła et al. (2021) empirically demonstrated that the expansion of information and communication technology reduced energy poverty in the EU during 2009-2019.

## 3. Data & Methodology

This research is based on panel data models that include more variables and refer by the EU countries from Central and Eastern Europe that are analysed in the period 2013-2023 because of the limited data availability. The dependent variable is represented by a proxy of energy poverty provided by Eurostat: total arrears on utility bills, % of total households- *arrears* and population unable to keep home adequately warm, % of total population- *pop*. The explanatory variables consist of: Internet development indicators provided by Eurostat (level of Internet access for households (percentage of households), frequency of Internet use for individuals, Internet use for individuals- *access, frequency* and *use*) and control variables provided by the World Bank (Renewable energy consumption as percentage of renewable energy use in total final energy use- *REC*, GDP per capita- *GDP*, foreign direct investment- *FDI*, Unemployment, total (% of total labor force) (modeled ILO estimate)- *unemp*l, Poverty headcount ratio at $2.15 a day (2017 PPP) (% of population)- *poverty*). The data are used in natural logarithm. The matrix of correlation for explanatory variables suggest**s** high correlation between GDP and REC (Pearson's coefficient=0.7113), GDP and Internet use (Pearson's coefficient=0.5497), between Internet access, frequency and use (coefficients higher than 0.9 between each two variables). Preliminary tests to check for cross-sectional dependence and unit root are applied before making the estimations. In case of stationary and integrated of order one data series, Pesaran & Smith (1995) Mean Group estimators (MG estimators) are calculated, since this method reduces endogeneity and allows us to work with data in level. The results in Table 1 for Pesaran's CD test suggest that cross-sectional dependence hypothesis is checked for all data series. The application of CADF test shows that only the data series for FDI, arrears on utility bills and Internet access are stationary in level, the data for the rest of the variables being stationary in the first difference.

**Table 1.** Preliminary tests to check for cross-sectional dependence and unit root (2005-2023).

| Variable | CD-test (p-value) | Data in level | | Data in the first difference | |
|---|---|---|---|---|---|
| | | CADF test (one lag) | CADF test (two lags) | CADF test (one lag) | CADF test (two lags) |
| REC | 8.04 (0.000) | 0.424 (0.664) | 2.066 (0.981) | -2.549 (0.005) | -2.660 (0.004) |
| FDI | 2.43 (0.015) | -4.210 (0.000) | -2.518 (0.006) | -3.751 (0.000) | -2.947 (0.002) |
| GDP | 9.82 (0.000) | -0.899 (0.184) | -2.545 (0.005) | -5.343 (0.000) | -6.124 (0.000) |
| access | 10.23 (0.000) | -2.470 (0.007) | -2.488 (0.006) | -3.288 (0.001) | -1.677 (0.047) |
| frequency | 10.25 (0.000) | -1.877 (0.030) | 0.550 (0.709) | -2.248 (0.012) | -4.335 (0.000) |
| use | 10.21 (0.000) | -2.977 (0.001) | -0.765 (0.222) | -3.012 (0.001) | -6.473 (0.000) |

| | | | | | |
|---|---|---|---|---|---|
| unempl | 8.99<br>(0.000) | -1.290<br>(0.098) | -1.170<br>(0.121) | -2.247<br>(0.012) | -1.611<br>(0.054) |
| poverty | 4.84<br>(0.000) | 2.387<br>(0.992) | 3.247<br>(0.999) | 6.285<br>(0.000) | 5.268<br>(0.000) |
| arrears | 4.26<br>(0.000) | -3.933<br>(0.000) | -2.487<br>(0.006) | -1.764<br>(0.039) | -2.800<br>(0.003) |
| pop | 7.10<br>(0.000) | -0.343<br>(0.366) | -0.881<br>(0.189) | -4.887<br>(0.000) | -4.966<br>(0.000) |

**Source:** own calculations in Stata

**4. Results**

The results of MG estimators (Pesaran & Smith (1995) Mean Group estimators) in Table 2 suggest that Internet development reduced the share of population unable to keep home warm, while REC increased the share of population unable to keep home warm. On the other hand, only Internet use and Internet frequency reduced the arrears on utility bills, while REC increased the arrears on utility bills. All in all, Internet development reduced energy poverty, while REC enhanced it in the V4 countries in the period 2005-2023.

**Table 2.** The impact of Internet development and REC on energy poverty in V4 countries (2005-2023).

| Var. | Dependent variable: pop | | | Dependent variable: arrears | | |
|---|---|---|---|---|---|---|
| access | -0.304***<br>(0.001) | - | - | -0.359<br>(0.157) | - | - |
| use | - | -0.400***<br>(0.001) | - | - | -0.547*<br>(0.072) | - |
| frequency | - | - | -0.373***<br>(0.002) | - | - | -0.560**<br>(0.023) |
| REC | 0.583***<br>(0.003) | 0.715***<br>(0.000) | 0.948***<br>(0.000) | 1.408**<br>(0.0387) | 1.867<br>(0.229) | 2.627*<br>(0.079) |
| Constant | 22.255***<br>(0.003) | 26.819***<br>(0.002) | 16.306***<br>(0.013) | 29.367***<br>(0.001) | 38.066<br>(0.001) | 20.004**<br>(0.046) |
| Residuals | I(0) | I(0) | I(0) | I(0) | I(0) | I(0) |

**Source:** own calculations in Stata 15. Note: p-value in brackets, * suggests p-value less than 0.1, ** suggests p-value less than 0.05, *** suggests p-value less than 0.01.

Robustness is checked by introducing additional control variables. The previous results are confirmed by the extended models. In addition, Table 3 suggests that unemployment increased energy poverty, FDI reduced share of population unable to keep home warm and increased the arrears on utility bills, while poverty had a direct impact on population unable to maintain home warm. GDP had no significant effect on energy poverty.

**Table 3.** The impact of Internet development, REC and additional variables on energy poverty in V4 states (2005-2023).

| Var.able | Dependent variable: pop | | | Dependent variable: arrears | | | | |
|---|---|---|---|---|---|---|---|---|
| access | -0.282** (0.02) | - | - | -0.228** (0.032) | -0.159 (0.441) | - | - | -0.274 (0.445) |
| use | - | -0.346** (0.016) | - | - | - | -0.190* (0.082) | - | - |
| frequency | - | - | -0.334*** (0.009) | - | - | - | -0.757** (0.047) | - |
| REC | 0.715* (0.071) | 0.681* (0.074) | 0.887** (0.01) | - | 1.200** (0.022) | 1.169 (0.229) | 2.768* (0.051) | - |
| unempl | 0.143* (0.061) | 0.776* (0.072) | 0.771* (0.077) | 0.366** (0.016) | 2.048*** (0.000) | 2.043*** (0.000) | 2.070*** (0.000) | 1.610*** (0.002) |
| FDI | -0.055* (0.074) | -0.043* (0.065) | -0.066** (0.044) | -0.162** (0.019) | 0.461** (0.015) | 0.446** (0.011) | 0.488*** (0.006) | 0.479** (0.01) |
| poverty | 1.811** (0.031) | 1.799** (0.039) | 1.774** (0.016) | 2.045* (0.057) | 0.883 (0.164) | -0.935 (0.195) | -0.893 (0.223) | -0.990 (0.259) |
| GDP | - | - | - | 0.0005 (0.575) | - | - | | -0.003 (0.166) |
| Constant | 18.239** (0.014) | 23.178*** (0.012) | 15.649*** (0.016) | 14.522 (0.147) | 4.858 (0.572) | 8.473 (0.446) | 3.937 (0.528) | 37.431 (0.252) |
| Residuals | I(0) | I(0) | I(0) | I(0) | I(0) | I(0) | I(0) | I(0) |

**Source:** own calculations in Stata 15.

Our results are in line with those of Postuła et al. (2021) that showed the reduction of energy poverty due to information and communication technology development in the EU in the period 2009-2019. Moreover, Qu and Hao (2021) also showed the capaicty of digital economy to reduce energy poverty in eastern and western provinces in the period 2011-2019.

However, REC does not contribute to less energy poverty and this challenge should be properly adressed. One cause might be the high costs of renewable energy sources in these countries and governments should contribute to their reduction.

**5. Conclusions**

Internet development can serve as a potential tool in the battle against energy poverty. By providing readily accessible information and resources on energy efficiency, the internet empowers individuals to adopt practices that reduce their consumption. While renewable energy is essential for long-term solutions, it can initially exacerbate energy poverty. This research also presents limitations. For example, the paper considers a small sample of countries and only few proxies for digital economy and energy poverty are considered. Future research might consider a comparative analysis between old and new EU member states and more variables to reflect the digital economy and the energy poverty, even an energy policy index based on the aggregation of more indicators.

Policy proposals based on these findings suggest several avenues. Firstly, it is imperative to harness the internet by developing and disseminating online resources. Secondly, governments from V4 states should prioritize making renewable energy more accessible through financial assistance programs and investments in grid modernization.

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