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The Impact of Information and Communication Technologies (ICT) on Energy Poverty and Unemployment in Selected European Union Countries

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Abstract: The accelerated development of information and communication technologies (ICT) over the last three decades has encouraged researchers to analyse the impact of this phenomenon on the labour market. The potential decline in employment resulting from the proliferation of ICT may reduce access to basic energy services and even lead to energy poverty in the form of inability to heat the apartment as needed, allocating a significant part of revenues to expenses related to heating or problems with the timely payment of energy bills. Because access to energy is of fundamental importance for improving the quality of life and is crucial from the point of view of economic development, it is justified to verify the hypothesis that the accelerated development of ICT in EU countries may contribute to an increase in unemployment and, consequently, translate into a higher level of energy poverty. The described research results were obtained thanks to a comparative factor analysis based on secondary data. The analysis showed that in the period 2009–2019, the use of ICT had a limited impact on the unemployment rate in the EU and had a significant impact on reducing the level of energy poverty in EU Member States. As regards the impact of ICT factors on the level of energy poverty, only IP traffic showed a significant impact in this area. When it comes to the labour market, it was found that employment is chiefly influenced by economic factors such as labour costs.

Keywords: ICT; unemployment; EU; energy poverty

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1. Introduction

The last few decades have seen a very intensive development of information and communication technologies (ICT). The development of the ICT sector has a very significant impact on the global economy in many dimensions. Many studies confirm that the development of ICT has a positive effect on economic growth and the productivity of enterprises. A significant and positive relationship between the development of the ICT market and economic growth is shown, for example, by the research conducted by Datta and Agarwal, Lam and Shiu, Ahmed and Ridzuan; and Pradham et al. [1–4].

When it comes to the analysis of the impact of ICT on the productivity of companies, there is a view that the improvement in productivity results from rapid technological progress. In industries using ICT, achieving an improvement in labour productivity is associated with the phenomenon of ICT capital accumulation, as it increases the productivity of employees. The use of ICT means introducing new ways of doing things and constantly improving technology through the gradual introduction of product and process innovations. An increase in productivity is particularly analysed in the context of R&D expenditure incurred by enterprises (including companies from the ICT sector), which contributes to the improvement of financial results ([5–8].

The above opinion was confirmed by the results of the research by Oliner and Sichel [9], who proved that the growth of ICT capital and industrial productivity in the computer sector accounted for two-thirds of the increase in average labour productivity in the USA in the late 1990s. Similar findings were made by Venturini [10], who, analysing the impact, showed that the growth of ICT capital in the United States and the EU-15 in the years 1980–2004 was the main factor influencing GDP growth in the same period.

Among the many aspects related to the development of research on ICT, the literature examines its impact on employment. Research confirms that in the long run, innovation and employment growth can be noted [11–14]. (Peters et al. [15] conducted a study of the relationship between innovation and employment at company level in the EU in 1998–2010. He revealed that in terms of employment, innovative firms are in a better position than non-innovative firms-regardless of the phase of the business cycle, they create more jobs during booms and busts periods and lose fewer jobs during recessions.

There are studies confirming that productivity gains account for a significant share of employment growth in many sectors in the EU, but this is particularly true of high-tech sectors [16]. ICT technologies recognised as the most important in the context of digitisation and their social and economic consequences include autonomous vehicles, additive manufacturing (3D-printing), algorithmic decision-making (big data), industrial and service robots, Bitcoin and blockchain technologies, digital factory ("Industrie 4.0"), smart home and active assisted living (AAL) [17]. As these ICTs can replace the routine activities of employees, it is believed that they will have a profound impact on the labour demand of the future.

There are studies confirming that job creation rate is specific to the sector in which a particular company operates. The differences between industries depend on the way available technologies are used, on the accumulated industry knowledge or on ways to protect and use innovations that bring economic benefits [18–20].

Another consequence of the impact of ICT factors on the labour market is an increased demand for skilled workers at the expense of unskilled workers, with the former benefiting from a wage growth and the latter experiencing a wage decline [21]. As ICT creates a greater demand for a highly skilled workforce—people who do not use new technologies will be increasingly disadvantaged in the labour market [22–24]. In this context, there is an ongoing debate as to whether the growing use of ICT, in addition to the reduced demand for certain professions, may result in an overall reduction in the number of jobs and an increase in the unemployment rate.

One of the most important effects of unemployment is the low standard of living of people affected by this social inequality, and therefore it can be expected to increase the level of energy poverty. Therefore, it makes sense to analyse whether, in the case of energy poverty, there is a link between ICT and the magnitude of this social inequality. Research by Nagaj and Korpysa [25] indicates that in the times of COVID-19, decline and increase in unemployment rate are the main determinants of the spread of energy poverty, which is reflected in lower average earnings from work. At the same time, according to the United Nations Department of Economic and Social Affairs (DESA), it is widely believed that ICT provides a new framework and significant opportunities for economic, political and social development. The World Summit for Social Development [26] has indicated that it is legitimate to facilitate access to such technologies for living people, as their use can help achieve human development goals.

The article attempts to verify whether the improved access to ICT and the increased use of these technologies actually had an impact on energy poverty and the unemployment rate. In the area of energy poverty, the authors attempted to verify the research hypothesis that the group of selected ICT factors for the European Union (EU) in 2009–2019 includes those that affect the level of energy expenditure (which is treated as one of the indicators of energy poverty). With regard to the labour market, the authors verified the research hypothesis that selected factors (including ICT factors) had an impact on the unemployment rate in a given EU Member State.

The verification of hypotheses should answer the question of whether there are any correlations between variables that have not yet been identified in the research, filling the research gap in this area. The possible demonstration of a correlation may have many practical implications for the development of solutions to enable closing the social inequalities gap in question.

In order to verify the formulated hypotheses concerning the presented research problem, a mixed methodology was used, which combines the results of qualitative and quantitative research.

The qualitative research relied on a comparative factor analysis based on secondary data and the quantitative research included the method of systematizing statistical information based on the statistical analysis of source data and the methodology of static dependencies, including fixed and random effect panel models.

2. Energy Poverty—The Impact of Energy Access on Inequality, Human Development and the Quality of Life

While a common definition of energy poverty has yet to be agreed on, the phenomenon has been identified as a priority in the EU [27]. It is estimated that around 30 million households in the EU live in energy poverty, which is understood as the inability to pay for the energy needed to adequately heat or cool their homes [28].

Energy poverty has many negative consequences on health by causing respiratory and cardiovascular diseases, and mental health problems caused, inter alia, by stress related to the inability to pay energy bills on time and the low educational attainment of children. Aggregate problems of citizens resulting from energy poverty have indirect consequences for many policy areas, including health, environment and performance. The benefits of reducing energy poverty are obvious and can be seen in areas such as reduced public health expenditure, cleaner environmental conditions, greater citizen comfort, higher household budgets, increased economic activity and, directly linked to it, an increase in the employment rate.

One of the main indicators of energy poverty is households being in arrears with payment of utility bills (heating, electricity, gas, water, etc.). Although the average number of such cases in the EU-28 in 2010–2017 decreased from 9 to 7%, the situation differs depending on the Member State. In 2017, the worst situation in this respect was in Greece, Bulgaria and Croatia, with 38% of Greeks, 30% of Bulgarians and 21% of Croats having problems with timely payment of bills due to financial constraints.

Research on explaining what constitutes the phenomenon of energy poverty is evolving. Originally, using the example of the northern European countries, it was considered that energy poverty was a combination of low-income, high energy prices and a low level of housing energy efficiency [29]. In a more recent interpretation, energy poverty is considered as the result of the adopted system solutions related to the socio-technical and administrative infrastructure.

Research by Primc et al. [30] highlighted the importance of climate and macroeconomic development as factors significantly contributing to energy poverty. It is increasingly pointed out that the key factors of energy poverty include the existing institutional structure and the decisions made at multiple levels of the network comprising public, private and non-governmental sectors. In this context, attention is drawn to the lack of justice in the distribution of social goods and to the material consequences of decisions of those in power [31–33]. This broad perspective can be found in the study by Teschner et al. [34] on "extreme" energy poverty in the Romanian and Israeli urban periphery, which results from a combination of policy, planning and infrastructure—including poor energy efficiency and access to energy issues.

There are studies that indicate gender inequality among the socio-demographic factors contributing to energy poverty [35] and that even the way people experience energy poverty varies by gender [36]. Oliveras et al. [37] show that gender and social class are responsible for the unequal distribution of energy poverty and are linked to increased use of health services and medicines.

In studies of southern European countries, in addition to the overall condition of the housing stock, the harmful effects of climate change are identified as key factors contributing to energy poverty—including rising temperature, more frequent heat waves, changes in wind and humidity and the urban heat islands (UHI) phenomenon [37].

There is also a strand of the debate that centres on the relationship between energy and transport, where the correlation between various forms of exclusion, infrastructure development, environmental policy and energy costs is analysed [38–40]

Research on electricity consumption has shown that it is positively correlated with the Human Development Index (HDI) and GDP. The analysis conducted by Ouedraogo [41] for a panel of 15 developing countries confirmed the significant positive impact of access to modern energy resources on HDI. Kanagawa and Nakata [42] showed, in a study of 120 countries, a significant correlation between electricity consumption and the Human Development Index (HDI) and GDP. Moreover, it was found that countries with higher levels of electricity consumption have high economic activity and Human Development Index scores. Niu et al. [43] conducted a panel study for 50 countries divided into four groups according to income for 1990–2009 and showed that, between electricity consumption and five indicators of human development, among which can be distinguished GDP per capita, level of expenditure, urbanisation rate, average length adult life and literacy, there is a long-term two-way relationship. The study also found that higher-income countries register higher electricity consumption and achieve higher levels of human development. In their later studies, Niu et al. [44] confirmed that electricity consumption is necessary to meet basic human needs, although in developed countries, when reaching the appropriate level, the increase in electricity consumption does not result in a corresponding increase in the quality of life. In a panel study of 120 countries, Martinez and Ebenhack [45] showed that there is a strong correlation between the UN Human Development Index and energy consumption per capita, and that in energy poor countries even a small increase in energy access has a positive effect on social development.

There is a view that energy poverty (resulting from insufficient access to modern energy services) is a direct consequence of income poverty [46]. There are many factors that contribute to income poverty. For many people, not finding a job with an adequate wage results in living off social benefits, putting those affected at risk of falling into energy poverty. Research confirms that the economic crisis and rising electricity prices have a negative impact, especially on the living standards of people with lower incomes [47].

The current literature largely agrees that energy poverty is associated with various problems, such as poor housing conditions and income poverty [48], lack of thermal insulation in homes [49], health problems of people living in cold houses [50] and in homes exposed to high temperatures in summer, excessive winter mortality [51–53], (difficulties with paying high energy bills [54] and difficulties with the quality of life in the household in general [55], 2010). Other causes of above-average energy demand may be the consequences of disability [56] as well as the lack of savings and the fact that the apartment is rented, which limits the possibility for the tenant to make changes to it [49].

Faced with energy poverty, households either spend above-average amounts of their income on heating, cooling, lighting, cooking and household appliances (which reduces expenses for other needs), or they forgo these expenses, which causes health problems, general discomfort and lowers their standard of living [57]. Both types of behaviour occur most frequently in energy-poor households, which may result in a significant deterioration of the physical and mental health of people [58–60]. Living in energy poverty also has an impact on daily practices, lifestyle and social exclusion [54,59,60].

3. Direct Employment Impact of ICT

In the context of the analysis of direct employment effects, there are two opposing concepts called the "theory of substitution" and "compensation theory". In the framework of the "theory of substitution", the aim is to determine if, and if so, to what extent, current human activities will be replaced by machines. The results of the findings are recognised as the potential to increase global unemployment. Researchers [61,62], analysed the processes involved in working for a set of jobs to determine which part of the process could be "automated" over the next several decades. An analysis of over 700 occupations [61] shows that nearly 50% of total employment in the US is at risk of being automated. Additionally, wages and education show a strong negative correlation with the probability of automation of a given profession. A similar study in Japan [62] showed that in the following years 55% of jobs should be considered as threatened with displacement by new technologies.

Similar but much more detailed research was performed [63] for 21 OECD countries with a task-based rather than occupation-based approach. Rather than analysing the whole process within a particular occupation, researchers considered smaller tasks within each process. It was found that on average only 9% of jobs can be said to be automatable, with the largest threat of up to 14% in Austria and Germany. These mostly involve work processes (tasks) where human interaction is perceived as not needed or demanded by a customer. These figures are in line with an average result of 15% in some later works on the subject [64], although the potential range presented in that research goes from 0 to 33%. Results vary widely across all 46 countries in question. It seems that advanced economies might be more affected by automation than developing ones. There still might be enough work to ensure full employment by 2030 due to increased demand for labour resulting from the economic growth.

Meanwhile, within the "compensation theory", the estimated "job at risk" does not necessarily mean actual or expected employment losses [63–65]. Bowles [66] conducted the study for the EU and concludes that between 47% (for Sweden) and up to well over 60% (Romania) of the EU work force will lose their job due to ICT in the coming decades. Bonin et al. [67] expect a reduction of 12% for Germany due to ICT and technological change.

It is true that Wolter et al. [68] found only a very small decrease in the total number of employees (−60,000) due to Industry 4.0 by 2030, but the model predicts very large structural changes in the manufacturing segment as well as between manufacturing and services: the total effect of the loss of 60,000 is the result of two parallel processes—a reduction of employment in industry by 420,000 jobs and a simultaneous increase of 360,000 jobs.

In a study by Pantea et al. [69], they found that there is no negative relationship between employment growth and the intensity of ICT use by companies, while Michaels and Graetz [70], studying the impact of robots on employment at the industry level in 1993–2007 in 17 countries, found a positive effect of increased use of robots in industry on productivity, wages and then on GDP growth. In terms of combined employment, they found a negative impact on low-skilled workers and a weaker impact on medium-skilled employment.

It is worth noticing that potential new occupations will likely emerge either directly in the ICT sector or in related services, both probably requiring a set of new skills. There is a strong trend within the proposed concepts that automation will transform rather than eliminate work [71]. Automation will probably drive steady redeployment of labour, but it will take decades rather than happen rapidly. Some comparison might be drawn between the technology changes in the previous technological shift in textile or steel industries [65].

Automation might not cause mass unemployment, but it may require workers to make disruptive transitions to new industries, requiring new skills and occupations. That conclusion is corroborated by the analysis of labour market in 1990–2012 in 19 OECD countries [72]. The latter goes even further, showing that implementing ICT requires an increase in employment at an early stage, followed by some decrease, but with the net result remaining positive. The same conclusion can be found in the aforementioned study [64].

A potential shift of jobs is one of the main takeaways from the assessment of the technology impact on the job market within the "compensation theory". The shift can be driven by the job complexity or by a specific skill set. The non-routine and specific set of skills makes new technology skill biased [73–76]. (The technology revolution might make a non-routine activity more productive but will likely consist in providing new tools rather than replacing human labour. Some specific skills are difficult to be automated, which is why it is stressed that the analysis should be performed with specific skill set in mind. The overall estimation shows that as many as 3 to 14% of the global workforce will see a change in their occupational categories [69].

Based on the findings so far from innovations, it can be concluded that the loss of employment is more than compensated by the increase in employment resulting from new technologies. Three effects are responsible for this compensation:

- The lower effect is due to additional investment in infrastructure and equipment that creates jobs in the sectors producing these capital goods;
- The second effect is due to lower ICT costs, which generates new demand and new jobs;
- The third effect results from the increased demand for new products from ICT-based innovations that will create new demand as well as new jobs [77].

This opinion is confirmed by other studies—the emergence of technological unemployment may be a consequence of increased productivity thanks to process innovations offered by ICT, which allow for producing goods and services with less labour. This effect is the stronger, the more labour-saving oriented the new technology is, i.e., the more ICT reduces the demand for labour in comparison with capital at constant prices of inputs for production. At the same time, innovations in ICT processes lead to lower unit production costs, which in a competitive market means lower prices. As a result, there is an increase in demand for products, which generates additional production and employment [78].

4. Description of Data and of the Research Model

In order to prove the hypotheses presented in the introduction, taking into account theoretical considerations, a decision was made to select all EU Member States for the static analysis in 2009–2019 with varied use of ICT in running a business. The choice of the analysis period resulted from the availability of data on the level of ICT advancement. The article presents the results of research for those EU countries where the most significant results were obtained.

Energy poverty can be measured using an expenditure approach that considers a household's energy expenditure, its share of income, etc. [79]. If a certain expenditure threshold is exceeded, the household is considered to be suffering from energy poverty. Such a threshold is set at 10% of household income or above the national median of household energy expenditure [80]. Taking into account that expenditure on satisfying households' basic energy needs is considered an indicator reflecting the level of energy poverty, the research conducted measured the impact of ICT in this area.

In the research concerning energy poverty, the study analysed whether there is a relationship between the following variables: IP traffic (PB/month), fixed Internet traffic (PB/month), mobile Internet traffic (PB/month), businesses with a broadband connection—including both fixed and mobile (%), businesses with a website offering online ordering or booking (e.g., shopping card) (%), a given sector's ICT share in the GDP generation and energy poverty defined as the energy expenditure by households in the EU countries.

When analysing selected ICT factors influencing energy poverty, after conducting the Hausman test, the random effect models turned out to be the models with better quality of parameter estimation (Table 1—details in the Appendix A in Table A1).

After removing statistically insignificant variables as regards the impact of the studied factors on energy poverty, only the IP traffic variable turned out to be significant (Table 2).

Table 1. Results of the research on the impact of selected factors on energy poverty using random-effects GLS regression.

Energy Poverty	Coef.	Std. Err.	z	$p > z$	[95% Conf.	Interval]
IP traffic (PB/month)	−0.00008	0.00004	2.09	0.04	−0.0001	−4.99
Fixed Internet traffic (PB/month)	0.0001	0.00007	1.66	0.10	−0.00002	0.0002
Mobile Internet traffic (PB/month)	−0.00007	0.00009	0.79	0.43	−0.0002	0.0001
Businesses with a broadband connection—includes both fixed and mobile (%)	−0.005	0.019	0.26	0.79	−0.043	0.033
Businesses with a website allowing for online ordering or booking (e.g., shopping card) (%)	0.013	0.018	0.74	0.46	−0.022	0.049
Sector ICT share in the GDP generation	−0.039	0.17	0.22	0.82	−0.379	0.302

Source: own study.

Table 2. Results of the research on the impact of IP traffic on energy poverty using random-effects GLS regression (details of Table A2 in the Appendix A).

Energy Poverty	Coef.	Std. Err.	z	$p > z$	[95% Conf.	Interval]
IP traffic (PB/month)	−9.02	8.4	−10.74	0	−0.00001	−7.38

Source: own study.

The relationship shown in the analysis, according to which an increase in IP traffic by 1 million units reduces energy poverty by an average of 9.02 units, is interesting to note in the context of growing IP traffic in recent years. Growth is extremely dynamic—according to Statista in 2017, global IP data traffic reached 121,694 petabytes per month, while in 2021 it is expected to be more than twice as large and reach 278,108 petabytes per month Taking the demonstrated relationship into account, one can expect an increase in the scale of the positive correlation between IP traffic and energy poverty in the future. It should be added that this is one of the secondary factors influencing energy poverty, because the model used explains the total variability of energy exclusion only in 2.16%.

In the case of the impact of the selected factors (including ICT factors) on the unemployment rate, a panel study was conducted that was based specifically on indicators such as the following: unemployment rate (response variable), Labour Cost Index by NACE, percentage of gross domestic product (GDP—compensation of employees, IP traffic, mobile Internet traffic and labour productivity in purchasing power standard (PPS)—compensation per employee.

The use of Internet traffic metrics was adopted as both the only and representative metric related to the development of digital economy. This is, first and foremost, an objective metric that, unlike many other indicators such as the percentage of companies using specific technological solutions, does not rely on subjective declarations. For the latter, even for positive answers it is hard to corroborate the extent to which a given technology is applied at a company. Therefore, companies that effectively use technologies may get the same treatment as those that only have a given technology in place but use it to a limited extent. Secondly, it is important that the Internet traffic metric is an accurate measure. A regular analysis of the quantity and type of data transferred is necessary to maintain a network's technical parameters (e.g., bandwidth), which is why the measurements and their available results reflect the actual situation in respective countries. Thirdly, whether the world is still at the stage of Third Technological Revolution [81] or has already entered the Fourth Technological Revolution [82], basic technologies determining the current level of development are as follows: robotisation, Internet of Things (IoT), cloud computing, artificial intelligence (AI/ML), distributed ledger technologies (DLT), quantum computers, biotechnologies, new mobile standard—5G, driverless vehicles and 3D printers. What makes these inventions feasible in business practice is the possibility to communicate through the worldwide computer network. Telecommunications development is seen as the cornerstone of the currently experienced technological breakthrough. Internet remains the core infrastructure necessary for the development of all the currently suggested technological innovations, which is why the authors consider the network traffic indicator to be representative enough.

It has enabled conducting quantitative research to suggest which of these factors has a significant impact on the unemployment rate in a given country. Typical coefficients such as level of education and age of employed persons are deliberately omitted in the analysis of this variable because the correlation with them has been researched in multiple studies and is scientifically confirmed.

A study was conducted using panel data involving 43 observations from 29 countries. The gaps in data relating to the technological progress for the full research sample have constrained the researchers to change the method applied to analyse both the random effects and fixed effects model upon conducting the Hausman test. The Hausman test estimates a fixed effects and a random effects model and compares the estimated coefficients. If the difference between the two is statistically significant, it means that the fixed effects assumption was wrong. The results obtained reveal that none of the models yielded reliable results (see: Tables A3 and A4 in Appendix A). Consequently, a decision was made to apply, in the unemployment rate analysis, linear models for each country individually due to the diversity of labour markets in the countries analysed. Linear models were determined using the ordinary least squares (OLS) method as a first step. Where the homoscedasticity assumptions were not met for the random component and no autocorrelation was found, the estimation was conducted using the generalised least squares method.

The following were determined for each model prepared for a given country: standardised and non-standardised regression coefficients, multiple R, R^2, adjusted R^2, standard error of estimate, variance analysis table, predicted values and residuals, as well as 95% confidence intervals for each regression coefficient and correlation and covariance matrices of the parameter estimates.

The top-down method was used to remove insignificant variables, assuming the significance level of 0.1 and assuming that high-quality models are those for which the determination coefficient is close to or greater than 0.9. Estimation results for respective countries, meeting such criteria, in which the most significant relationships between the studied variables were found, are presented in Table 3.

Table 3. OLS analysis results for the selected EU Member States.

Country	Labour Cost Index by NACE	GDP Growth—Compensation of Employees	IP Traffic (PB/month)	Mobile Internet Traffic (PB/month)	Fixed Internet Traffic (PB/month)	Labour Productivity in PPS—Compensation per Employee	_cons	N	r2	r2_a
Croatia	0.24		0.0007	−0.002	−0.0007		10.23	8	0.97	0.94
Cyprus			0.001	−0.002	−0.001		4.1	18	0.96	0.95
Germany	−0.66			0.0006	−0.0001		10.57	19	0.91	0.89
Greece	−0.31		0.0004	−0.003		−0.001	32.98	16	0.98	0.97
Ireland	−0.77	0.49	−0.0007	−0.002	0.001	−0.0003	0.6	16	0.97	0.95
Italy	0.54		0.0005	−0.001	−0.0005	−0.0007	26.3	16	0.98	0.96
Latvia	−0.45	−0.88	−0.0007	0.001	−0.0004	0.002	42.93	16	0.95	0.93
Lithuania	−0.45	−0.64			0.001	0.0002	37.97	16	0.98	0.97
Malta	0.09				−0.00003		6.73	16	0.92	0.91
Portugal				−0.002	0.0003	0.0005	−3.02	19	0.94	0.93
Spain		1.96		−0.005	0.0008	−0.001	−59.72	19	0.91	0.89
United Kingdom	−0.21	0.51	−0.00021	−0.0007	0.0004	−0.0001	−15.84	16	0.96	0.94

Source: own study.

In Croatia, the unemployment rate is significantly impacted by labour costs and indicators measuring the level of ICT use. The results obtained indicate that an increase in labour costs by one unit causes the unemployment rate to rise by 0.2 percentage points. However, at the same time it can be observed that, in this situation, entrepreneurs start to look for solutions to reduce the labour cost and opt for solutions involving new technologies, because for mobile Internet traffic and fixed Internet traffic, an increase by 1 unit causes the unemployment rate to drop by 0.002 p.p. and 0.0007 p.p., respectively. In Cyprus, the impact on the unemployment rate is only observable for indicators related to the use of new technologies, i.e., mobile Internet traffic and fixed Internet traffic, the increase of which causes the unemployment rate to drop. Only for IP Internet traffic can one observe that its increase will significantly contribute to a higher unemployment rate in both countries. When it comes to one of the largest economies that is Germany, it has been demonstrated that the Labour Cost Index and fixed Internet traffic have a significant impact on the unemployment rate, namely they cause it to go down. Meanwhile, an increase in mobile Internet traffic by one unit in this country causes the unemployment rate to rise by the barely noticeable 0.0005 p.p. In Ireland, similarly to Germany, labour cost is not a factor that drives up the unemployment rate; on the contrary, an inverse and quite high correlation is noticeable (an increase of the Labour Cost Index by NACE by 1 unit causes the unemployment rate to drop by 0.77. Meanwhile, an increase in GDP growth—compensation of employees by 1 unit in this country causes the unemployment rate to rise by as much as 0.49 p.p. IP and mobile Internet traffic are significant, but the correlations are very minor and contribute to a lower unemployment rate in Ireland.

In the Baltic States, i.e., Lithuania and Latvia, the results are very similar and so is the impact of explanatory variables selected for the analysis on the unemployment rate. Labour cost has nearly exactly the same significant impact on the unemployment rate, i.e., an increase in the Labour Cost Index by NACE will cause the unemployment rate to rise by ca. 0.45 p.p. Similarly, both in Lithuania and Latvia, an increase by 1 unit in GDP growth—compensation of employees causes a significant unemployment rate growth by 0.68 p.p. and 0.88 p.p., respectively. Fixed Internet traffic is significant, but its impact is of the order of thousandths, barely affecting the unemployment rate. For Malta, of all the ICT indicators selected, only fixed Internet traffic has a significant negative impact on the unemployment rate, the other parameters being of little significance.

Greece came out economically devastated from the last economic crisis of 2007–2009, which undoubtedly affected the situation on the labour market. The country has another important characteristic: tourism and agriculture have the highest contribution to GDP, both sectors being highly labour intensive, as corroborated by the analysis results. The country's unemployment rate significantly depends on labour cost and increases by 0.31 p.p. if the Labour Cost Index by NACE rises by 1 unit. The impact of ICT parameters on the labour market situation is minor, which can be due to the aforementioned specificity of the country's economy. Of great interest are the results obtained for Portugal and Spain, countries characterised by a high unemployment rate, especially among young people. Research results are very similar and surprisingly indicate a lack of impact of labour cost on the unemployment level, which may mean that other characteristic features of those populations (demographics, social behaviours, etc.) play a much greater role. The selected indicators relating to technological changes are of no significance and their impact is negligible, with unemployment rate falling by 0.46 p.p. in Spain and by 0.02 p.p. in Portugal, if the level of mobile Internet traffic rises by 1 unit. An inverse correlation exists for fixed Internet traffic. In both countries, the unemployment level is also significantly affected by labour productivity in PPS—compensation per employee; in Spain, the indicator has a positive impact on the unemployment level, while in Portugal the labour market reacts in the opposite way. Even though Italy is categorised as a so-called southern European economy, the research findings are slightly different. First of all, the unemployment rate there depends on the Labour Cost Index by NACE, i.e., an increase in this indicator by 1 unit leads to unemployment rate rising by 0.54 p.p. Such dissimilarity cannot be observed for other explanatory variables; however, in Italy, an increase by 1 unit in mobile Internet traffic causes the unemployment rate to fall by 0.012 of a unit. Other ICT parameters are significant also in this country, but the correlations obtained can be hardly considered as capable of visibly impacting the unemployment level.

In the United Kingdom, which has already exited the EU, but during the period under analysis was still a member, the unemployment rate is significantly correlated, increasing in proportion to variables such as GDP growth—compensation of employees, mobile Internet traffic and fixed Internet traffic. Meanwhile, for the Labour Cost Index by NACE and labour productivity in PPS—compensation per employee, the correlation is weak and the increase in those indicators causes the response variable to go down.

5. Discussion

The prerequisite for conducting research on the possible negative impact of ICT on the labour market and, consequently, an increase in the unemployment rate is the phenomenon of automation of certain professions. The problem is analysed in the literature, and research on this topic has been cited by the authors and is potentially large. Research by Frey and Osborne on the susceptibility of 700 professions to automation, estimate that as much as 47% of workers in the United States work in jobs that are prone to automation, and only one-third in those where the risk is low [61].

The research carried out by the authors for the European Union countries with the use of selected ICT factors characteristic for the confirmation of the use of ICT does not prove that this risk has materialised. The findings are similar (though different) to the research findings that the unemployment rate in the EU is broadly stable despite the huge improvement in information technology [64].

The article presents the results of the study of the impact of the selected factors (including ICT factors) on unemployment for 12 EU Member States (before Brexit), for which the obtained correlations were the most important and therefore may constitute the basis for further analysis. For the remaining 16 EU Member States, the obtained results do not allow for drawing reliable conclusions based on the models. The analyses conducted have revealed that in nine of the countries analysed, the Labour Cost Index by NACE is a significant driver of employment level, though its impact varies greatly between countries. Where the working-age workforce is abundant rather than in short supply (Croatia, Italy, Lithuania, and Malta), an increase in labour cost leads to an increase in the unemployment rate, which seems to be a natural though not prevalent phenomenon for all EU countries. In other countries an inverse correlation can be observed, i.e., the increase in labour cost does not cause the unemployment rate to rise, which seems to be confirmed also by labour immigration into those very countries. Germany, United Kingdom and Ireland are countries where the demand for labour is greater than the available human resources, which is why an increase in labour cost, rather than giving rise to redundancies and a growing number of the unemployed, inspires the search for new solutions to help reduce this cost in future

Taking Germany, United Kingdom and Ireland as an example, this study demonstrates that, with an appropriate labour market structure, even a negative correlation between the labour cost and the unemployment level can be obtained. This may mean that these economies achieve a competitive advantage otherwise than by low labour cost alone. Still, no particular correlation between the unemployment rate and technological level can be observed in those countries. Perhaps this is the effect described in the literature by the "compensation theory", but this issue remains to be investigated.

Unlike a number of papers cited by the authors [61,63,64], this study does not reveal a major threat for the employment level posed by high technologies. The highest obtained correlations between technology indicators, especially to the development of mobile Internet traffic, are only visible in the third decimal digit. This is two orders of magnitude lower than for factors relating to the compensation of employees. The result obtained indicates that overlooking the economic questions in the research to date has led to an oversimplified model. In the studies cited the processes were analysed from the perspective of feasibility of replacing human work with machine work; hence, only a potential for possible change was indicated. However, a change will only be actually introduced in companies if a valid economic reason is found, that is, if a satisfactory "business case" is successfully created. The amount of compensations of employee is of the greatest importance from the point of view of creating such a "business case".

In terms of the impact of ICT on energy poverty, the existence of a link between this social inequality and the unemployment rate, for example in the context of an overly large share of energy expenditure in the household budget, which is often linked to the fact of a lack of employment income, fully justifies the study of the impact of ICT factors.

The authors' demonstration of the lack of impact of ICT on the unemployment rate in the EU countries in the analysed period (despite indicating the risks in the studies cited on this subject) while confirming that ICT has an impact on reducing energy poverty carries significant research consequences in this area. Because the problem of the impact of ICT on energy poverty in the literature is rarely present and the problem will grow with the simultaneous increasing spread of ICT, the analysis of dependencies in the triangle ICT–energy poverty–unemployment rate may allow us to identify the most important relationships that can be used in developing public policies at the level of the EU Member States and the entire EU.

Taking into account the ongoing discussion on the underrepresentation of the ICT sector in the classical method of calculating GDP (according to this measurement system, ICT companies have no more than a one-digit share in GDP and the number of employees in any country), it seems justified to search for new indicators that capture the hidden influence of this sector on the economy. According to some studies, the "hidden" ICT sector mainly consists of services provided by online platforms. This means that network traffic, a measure adopted in our research, will remain profitable in this case as well. However, if the dynamics of network traffic are very weakly correlated with changes in employment levels in the analysed countries, it can be hypothesised that the "hidden" impact of ICT on GDP is much lower than estimated by some researchers. Alternatively, it can be assumed that a potential threat to the labour market is this "hidden" ICT market, the services of which are provided automatically and do not affect the employment level, especially in the analysed countries. This argument is supported by the relatively low level of employment in companies operating digital platforms. For this process to threaten the labour market on a large scale, fully virtual services would need to become more widespread.

6. Conclusions

Energy poverty (including income and energy poverty) and low unemployment are the main challenges currently facing the global economy, including the EU. In this context, the awareness that ICT can reduce income poverty by improving access to education, healthcare, public or financial services, which is reason enough to make it the subject of further and regular research.

In the case of the Member States of the EU, the interest of competent authorities in the issue of energy poverty is a relatively new phenomenon. Due to the additional fact that energy poverty is a heterogeneous and multidimensional phenomenon [80], the proposed measures to reduce it can be implemented in many areas, including changes in the living environment [82–84], new technologies [85,86], policies and legislation [87], financial schemes [88] and energy transition [89].

There are known examples of reducing energy poverty with the use of ICT in certain sectors. This applies to sectors such as energy, industry and transport, where an estimated 15% reduction in energy consumption is possible.

Considering that energy is primarily consumed by electrical devices, reducing the level of energy exclusion can be achieved by applying ICT solutions in areas related to their use, such as:

- Network modernisation;

- Using energy-saving software;
- Quick implementation of new solutions (e.g., 5G networks) without installing energy-consuming devices;
- Intelligent local infrastructure management (e.g., by remote troubleshooting).

Within the framework of the hypotheses put forward by the authors, it was possible to confirm that the selected ICT factors did not contribute to the increase in unemployment in the EU countries in the analysed period, and that one of the ICT factors (IP traffic—PB/month) contributed to the reduction of energy poverty.

In the case of unemployment, the authors' research on the impact of ICT on unemployment suggests that the growing role of ICT in socio-economic life has little impact on the labour market in EU countries. The results for the 2009–2019 data showed that there were no signs of a digital sector impact on employment levels. The demonstrated correlations between employment rates and technological advancement measured by network traffic indicators are two orders of magnitude lower than the corresponding correlations between employment and economic indicators. Confirmation of a greater scope of impact on the unemployment rate of factors such as labour cost may justify the direction of further research regarding, for example, the impact of ICT on labour costs, or an attempt to develop indicators that take into account the "hidden" impact of the ICT sector, which will allow researchers to verify the strength of its impact on the level of employment.

Despite the research findings that ICT does not contribute to the increase in unemployment, it seems justified to repeat this type of research in the future, because the phenomenon in which decisions about replacing human work with technology need to be made will increase. As agreed, the labour market will only be at risk if the impact of this new technology significantly changes the existing cost-effectiveness ratio between the use of technology and human labour. While the potential of modern digital technologies to replace people in their tasks is almost limitless, in most cases, humans still remain the cheapest part of any production process.

Taking into account the results of the research carried out by the authors, which confirmed the positive impact of ICT on reducing energy poverty, due to the social importance and the growing scale of this negative phenomenon, it is justified to deepen research in this area. At the same time, bearing in mind the complexity of the problem of energy poverty, it must be taken into account that the scope of further research will go beyond the area of new technologies and will include solutions from other areas that may have a positive impact on reducing this social inequality.

At the same time, the existence of studies that confirm the thesis that the level of unemployment varies depending on which groups of employees are at risk of automation (unemployment is much higher in occupations for which the risk of automation is higher) should target specific segments of employees. In Poland, according to data for 2015, unemployment in professions with a low risk of automation was 4%, in the group of professions with a moderate risk of automation it was 8%, and in high-risk professions it was 12% [90].

The scale of differences in the level of unemployment depending on the occupational group is so large that, in the authors' opinion, the continuation of research on the impact of ICT factors on the unemployment rate and energy poverty should take into account the segmentation of employees from the perspective of the threat of automation to a greater extent than analysing the dependencies from the perspective of total unemployment rate for a specific country.

Notwithstanding the fact that the results of the research conducted by the authors did not confirm the view that the use of ICT increases the unemployment rate in EU Member States, the impact of ICT on unemployment, deterioration of household incomes and increase in energy poverty among EU citizens will be more significant in the future than at present. Taking into account the fact that, in the EU Member States, the impact of ICT is different due to the needs of the economy, the specialisation of individual sectors or even the size of the population, the authors consider extending research in this area, taking into account the resulting specificity. In the context of further research on the impact of ICT factors on the unemployment rate, a separate analysis requires both the identification of ICT factors other than those selected by the authors in the presented research, as well as verification of whether the analysis should take into account the different degree of ICT penetration in various sectors of the economy.

For the EU, energy poverty is considered a significant problem, which translates into supporting action plans prepared by EU Member States, including social policies and measures to improve energy efficiency [87]. These actions should be seen as steps in the right direction. However, their scope should be related to the monitoring of the scale of the problem, which is related to, inter alia, with the need to develop universal tools for measuring energy poverty.

The role of ICT in the social life of the EU countries will increase in the future. This is due both to objective reasons related to global technological progress processes, but also to the implementation of the EU's economic assumptions, according to which it would become the most innovative area in the world. Due to the fact that the phenomena of energy poverty and the unemployment rate in the EU countries will be of increasing importance in the social, economic or political dimension, the continuation of further research on the interpenetration of these areas, in the opinion of the authors, is perfectly justified and will be implemented by them in the future.

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Appendix A

Table A1. Results of the research on the impact of selected variables on energy poverty using random-effects GLS regression.

Random-Effects GLS Regression	Number of Obs.	=	117			
Group variable: country	Number of groups	=	21			
R-sq:	Obs. per group:					
within = 0.4808	min	=	1			
between = 0.0451	avg	=	5.6			
overall = 0.0540	max	=	7			
	Wald chi2(6)	=	86.85			
corr(u_i, X) = 0 (assumed)	Prob > chi2	=	0.0000			
Energy Poverty	Coef.	Std. Err.	z	$p > z$	[95% Conf.	Interval]
IP traffic (PB/month)	−0.000079	0.0000377	2.09	0.04	−0.000153	-4.99×10^6
Fixed Internet traffic (PB/month)	0.0001128	0.0000681	1.66	0.10	−0.0000206	0.0002462
Mobile Internet traffic (PB/month)	−0.0000732	0.0000925	0.79	0.43	−0.0002545	0.000108
Businesses with a broadband connection—includes both fixed and mobile (%)	−0.0051663	0.0195896	0.26	0.79	−0.0435612	0.0332287

Table A1. *Cont.*

Businesses with a website allowing for online ordering or booking (e.g., shopping card) (%)	0.0134516	0.0180649	0.74	0.46	−0.0219549	0.0488581
Sector ICT share in the GDP generation	−0.038718	0.1736519	0.22	0.82	−0.3790693	0.3016334
_cons	5.936325	1.964087	3.02	0.00	2.086785	9.785865
sigma_u	1.932101					
sigma_e	0.41037531					
rho	0.95683423		(fraction of variance due to u_i)			

Source: own study.

Table A2. Results of the research on the impact of IP traffic on energy poverty using random-effects GLS regression (details).

Random-Effects GLS Regression	Number of Obs.		224			
Group variable: country	Number of groups		32			
R-sq:	Obs per group:					
within = 0.0000	min		7			
between = 0.0000	avg		7.0			
overall = 0.0216	max		7			
	Wald chi2(1)		115.43			
corr(u_i, X) = 0 (assumed)	Prob > chi2		0.0000			
Energy poverty	Coef.	Std. Err.	z	*p* > z	[95% Conf.	Interval]
IP traffic (PB/month)	−9.02	8.4	−10.74	0	−0.00001	−7.38
_cons	5.47	0.32	17.09	0	4.84	6.09
sigma_u	1.78					
sigma_e	0.37					
rho	0.96		(fraction of variance due to u_i)			

Source: own study.

Table A3. Results of the research on the impact of selected variables on unemployment using random-effects GLS regression.

Random-Effects GLS Regression	Number of Obs.		430			
Group variable: country	Number of groups	=	29			
R-sq: within = 0.2989	Obs. per group: min	=	8			
between = 0.3364	avg	=	44057			
overall = 0.3274	max	=	19			
	Wald chi2(6)	=	183.42			
corr(u_i, X) = 0 (assumed)	Prob > chi2	=	0.0000			
Unemployment	Coef.	Std. Err.	z	*p* > z	[95% Conf.	Interval]
IP traffic (PB/month)	0.0000939	0.000108	0.87	0.385	−0.0001178	0.0003056
Labour Cost Index by NACE	−0.341858	0.0359479	−9.51	0.000	−0.4123145	−0.2714014
Fixed Internet traffic (PB/month)	−0.000063	0.0001607	−0.39	0.695	−0.000378	0.000252
Mobile Internet traffic (PB/month)	−0.0005431	0.0001155	−4.70	0.000	−0.0007694	−0.0003168

Table A3. *Cont.*

GDP growth—compensation of employees	−0.0294437	0.0594593	−0.50	0.620	−0.1459818	0.0870944
Labour productivity in PPS—compensation per employee	−0.0001505	0.0000275	−5.47	0.000	−0.0002044	−0.0000966
_cons	15.13228	2.514773	43,867.00	0.000	10.20342	20.06115

Source: own study.

Table A4. Results of the research on the impact of selected variables on unemployment using fixed-effects GLS regression.

Fixed-Effects (within) Regression	Number of Obs	=	430			
Group variable: country	Number of groups	=	29			
R-sq: within = 0.3014	Obs per group: min	=	8			
between = 0.2895	avg	=	44,057			
overall = 0.2916	max	=	19			
	F(6395)	=	28.41			
corr(u_i, Xb) = −0.2581	Prob > F	=	0.0000			
Unemployment	Coef.	Std. Err.	t	$p > \mathrm{t}$	[95% Conf.	Interval]
IP traffic (PB/month)	0.0000735	0.0001088	0.68	0.500	−0.0001405	0.0002874
Labour Cost Index by NACE	−0.3260734	0.0366937	−8.89	0.000	−0.3982128	−0.2539341
Fixed Internet traffic (PB/month)	−0.0000196	0.0001645	−0.12	0.905	−0.0003429	0.0003037
Mobile Internet traffic (PB/month)	−0.0006096	0.0001265	−4.82	0.000	−0.0008583	−0.0003608
GDP growth—compensation of employees	−0.00251	0.0698664	−0.04	0.971	−0.1398664	0.1348464
Labour productivity in PPS—compensation per employee	−0.0002039	0.0000477	−4.27	0.000	−0.0002977	−0.0001101
_cons	14.93886	3.068899	4.87	0.000	8.905443	20.97228

Source: own study.

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