

SUSTAINABLE PRACTICES IN ENTERPRISES IN THE CONTEXT OF ICT DEVICES USAGE

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Purpose: Study on the level of implementation of sustainable practices in Polish enterprises in the field of ICT equipment management in NUTS-2 regions in Poland.

Design/methodology/approach: The study employs methods of multivariate statistical analysis to comprehensively assess and compare the extent of sustainable ICT practices in different regions. Data from the Polish Central Statistical Office for 2022 were analysed, focusing on five key indicators: reduction of printed paper, energy efficiency measures for ICT, environmentally conscious ICT procurement, proper disposal of electronic waste, and practices of reusing or returning ICT equipment.

Findings: The results reveal significant regional disparities. The Warszawski Stołeczny region leads in implementing sustainable ICT practices, underpinned by advanced infrastructure and a high degree of environmental awareness among enterprises. In contrast, regions like Lubuskie and Mazowiecki Regionalny exhibit lower levels of pro-environmental ICT activities, reflecting weaker economic conditions and infrastructure. The research supports the hypothesis of a positive correlation between regional economic development and the implementation of sustainable ICT practices.

Research limitations/implications: The study's limitations include reliance on data from a single year, restricting the ability to identify trends over time. Future research could extend to longitudinal analyses and explore additional variables, such as the influence of regional policies or cultural factors on environmental practices.

Practical implications: The findings can guide policymakers and regional authorities in designing targeted interventions to promote sustainable ICT management, especially in less developed regions. Businesses may use these insights to align their practices with regional benchmarks, enhancing both environmental performance and regulatory compliance.

Social implications: The research informs policy measures and corporate social responsibility initiatives, ultimately contributing to improved environmental outcomes and public awareness.

Originality/value: This study provides a novel regional analysis of sustainable ICT practices in Poland, offering a valuable framework for comparing and improving environmental management across diverse economic landscapes. It is relevant to policymakers, environmental researchers, and business leaders.

Keywords: sustainable ICT practices, regional analysis, multivariate analysis, environmental management, corporate social responsibility.

Category of the paper: Research paper.

1. Introduction

In the face of growing challenges related to environmental protection and sustainable development, enterprises must adapt their practices concerning the use of information and communication technologies (ICT) in a responsible and eco-friendly manner. In an era of dynamic technological advancement, the use of ICT devices has become indispensable; however, their production, operation, and disposal can generate significant environmental burdens. In this context, there is a need to identify and evaluate sustainable ICT management practices in enterprises.

This article aims to examine the level of implementation of sustainable practices in Polish enterprises regarding ICT management across NUTS-2 regions in Poland. These regions encompass the administrative division of Poland, including the specificity of the Mazowieckie Voivodeship, which is split into the Warsaw capital region and the Mazowiecki regional area.

The research hypotheses are as follows:

1. There are significant differences in the implementation of sustainable ICT practices between regions in Poland, which may result from varying economic development levels and environmental awareness.
2. The Warsaw capital region is characterized by a higher level of implementation of eco-friendly actions in ICT management compared to other regions.
3. A higher level of economic development in a region (measured by the development index) is correlated with more frequent adoption of sustainable ICT practices.

The study used publicly available data from 2022, obtained from the Polish Central Statistical Office, concerning the impact of ICT devices on the environment within the Polish economy. The data analyzed pertain to the percentage of enterprises that consider selected environmental aspects within designated administrative areas of Poland.

1. Overview of sustainable business practices

Recent research on ICT equipment and environmental protection highlights both positive and negative effects. While ICT can improve environmental sustainability through digitalization and energy efficiency (Charfeddine, Umlai, 2023), it also contributes to CO₂ emissions and energy consumption (Siddiqui et al., 2014; Bull, 2015). In turn, Szalkowski et al. (2024) in a review of the scientific literature identified eight main classes of solutions regarding the impact of ICT on the environment, aligning them with the UN Sustainable Development Goals. Bieser and Hilty (2018) also assessed the indirect negative environmental effects of ICT in their research. To mitigate the negative effects of ICT, researchers propose,

for m.in, environmentally friendly devices and green computing approaches (Siddiqui et al., 2014). A review of the literature on the pro-ecological activities of enterprises in the use of office equipment confirms the possibility of reducing energy consumption in office environments. Studies have shown that optimizing the location and allocation of printing devices can lead to significant reductions in electricity consumption and carbon emissions (Kaszyński et al., 2021). Deploying energy-efficient ICT equipment and promoting good practices such as proper device management and energy-saving settings can further reduce energy consumption in commercial buildings (Kamilaris et al., 2014; Wysocki, 2016). In addition, the scientific literature confirms that the use of ambient technologies to increase awareness and encourage employees to compete effectively reduces the energy consumption associated with lighting in public areas of office buildings (Coutaz et al., 2018). Other research indicates that promoting eco-friendly printing behaviour can significantly reduce paper consumption and associated costs in offices. A study conducted in Dutch primary schools found that reinforcing pro-ecological values led to a 45-51% reduction in printing (Suleri, 2018). Other studies on green printing behavior also support these findings (Suleri, Cavagnaro, 2016). Companies that adopt proactive environmental strategies can gain a competitive advantage by reducing costs, improving product quality, and better relationships with stakeholders (Seroka-Stolka, 2012). These results indicate that the promotion of sustainable values and the use of technology can effectively reduce printing and its environmental impact in various areas.

Another problem in the field of office equipment is its disposal. Recent research highlights the importance of efficient collection systems for waste electronic equipment (Anuradha, 2024; Lu et al., 2017; Friege et al., 2015). This is also becoming an area that requires procedural changes in office management in enterprises.

2. Methodology

The study used publicly available data collected from the website of the Central Statistical Office (GUS) on pro-ecological practices in enterprises in the area of the use of ICT equipment in 2022 Polish. In particular, comparative analyses were used, which allow for a comprehensive grasp of the complex phenomenon of implementing pro-ecological practices and the assessment of regional differences in this area. These methods are particularly useful for the purpose of the article for several reasons. Firstly, they allow the assessment of a complex phenomenon – the variables used in the study relate to different aspects of the sustainable management of ICT devices, which creates a complex picture of the pro-environmental activities undertaken by companies. Multivariate methods allow these variables to be combined into one coherent index that synthetically describes the level of implementation of sustainable practices. The variables analysed include: the share of companies reducing paper printing, the share of companies

reducing the energy consumption of ICT equipment, the share of companies taking environmental protection into account when choosing ICT equipment, the share of companies returning waste equipment to appropriate collection points, and the percentage of companies selling, charitable or returning unused equipment to the lessor. Secondly, these methods make it possible to identify differences between regions (voivodeships). By using measures of distance from the development pattern and the development index, it is possible to determine how different regions differ in terms of the advancement of pro-ecological activities. Comparative analysis takes into account the multifaceted nature of the phenomenon, which allows for accurate identification of regions ahead and lagging behind the pattern. Thirdly, in the context of this study, these methods make it possible to rank and classify regions according to the level of implementation of sustainable practices. This makes it possible to identify those regions that require specific support in the field of sustainable management practices of ICT equipment in enterprises.

In the methods of multivariate statistical analysis, and especially in the methods of linear ordering, it is important to distinguish variables according to their nature. We distinguish stimulants, i.e. variables whose higher values are desirable in the context of the phenomenon under study, destimulants, i.e. variables where higher values are unfavorable, and nominates for which deviations from the optimal level are undesirable (Zawada, 2009). Linear ordering methods are widely used, in particular when assessing the diversity of objects due to the level of economic development achieved. The study assumed that the level of influence of all variables (X1-X5) on the analyzed phenomenon is the same. The similarity of objects (the closer the values of the variables describing a given complex phenomenon, the more similar the objects are to each other) was measured by the distance between objects, which assigns one value to two objects. Thus, the Euclidean distances of individual objects in relation to the model object were determined (Mesjasz-Lech, 2018):

$$d_{i0} = \sqrt{\sum_{j=1}^m (z_{ij} - z_{0j})^2} \quad (i=1, \dots, n) \quad (1)$$

whereas,

$$z_{0j} = \begin{cases} \max_i z_{ij} & \text{for stimulants} \\ \min_i z_{ij} & \text{for destimulants} \end{cases} \quad (2)$$

The measure of development was estimated using the formula:

$$m_i = 1 - \frac{d_{i0}}{d_0} \quad (i=1, \dots, n), \quad (3)$$

For such a measure of development with values in the range [0,1], it is assumed that the higher its value, the higher the level of the phenomenon under study.

The methodological approach adopted allows for an in-depth analysis of the phenomenon, as well as offers tools to identify and assess potential regional differences. The results of the analysis will provide comprehensive knowledge on the spatial diversity of the implementation of pro-ecological practices in ICT equipment management in Poland, which is a valuable basis for the recommendation of sustainable development policy.

3. Results

First, the data collected from the Central Statistical Office were analyzed. The variables X1-X5 are specified in relation to the NUTS-2 regions in Poland (Table 1). These data show significant variation between regions. The Warsaw Capital Region is distinguished by the highest values for most indicators, which may be related to the developed technological infrastructure, high level of investment in new technologies and greater environmental awareness among companies operating in the capital. The values for this region in terms of reducing paper printing (61.1%), reducing energy consumption (45.4%), and taking environmental aspects into account when choosing equipment (67.8%) are among the highest in the country. The percentage of companies handing over or returning waste ICT equipment also stands out in particular, at 34.7%, the highest rate in the entire analysis.

Table 1.

Share of enterprises using pro-ecological solutions in the area of ICT equipment use by NUTS-2 regions in Poland in 2022

NUTS-2 region	X1	X2	X3	X4	X5
Dolnośląskie	57.4	43.3	63.4	70.2	24.4
Kujawsko-pomorskie	53.2	44.0	62.3	68.8	19.5
Lubelskie	52.9	42.7	59.4	67.8	19.3
Lubuskie	50.2	37.6	60.3	62.5	21.7
Łódzkie	51.0	43.3	62.8	67.3	18.4
Małopolskie	57.3	44.8	61.5	67.7	23.1
Warszawski Stołeczny	61.1	45.4	67.8	71.1	34.7
Mazowiecki Regionalny	51.7	39.0	63.2	66.7	16.9
Opolskie	52.4	41.3	63.6	71.6	24.0
Podkarpackie	53.8	42.6	63.3	70.0	17.0
Podlaskie	52.3	38.8	66.4	69.7	17.5
Pomorskie	55.4	43.0	64.0	75.1	21.4
Śląskie	55.4	42.5	66.4	70.0	23.3
Świętokrzyskie	51.6	41.3	66.4	65.4	16.6
Warmińsko-mazurskie	51.8	43.9	65.8	70.5	17.4
Wielkopolskie	54.9	44.2	63.8	68.7	22.0
Zachodniopomorskie	53.7	41.5	64.8	70.5	21.1

Note. X1 - share of enterprises reducing paper printing, X2 - share of enterprises reducing energy consumption of ICT equipment, X3 - percentage of companies taking into account environmental protection when choosing ICT equipment, X4 - share of enterprises returning waste equipment to appropriate collection points, X5 - percentage of companies selling, donating to charity or returning to the lessor.

Source: own elaboration based on [GUS].

On the other hand, regions such as Lubuskie, Świętokrzyskie and Mazowiecki Regionalny are characterized by lower values for most variables, which may be the result of weaker economic infrastructure, lower expenditure on innovation and a smaller number of large enterprises, which often lead in the implementation of pro-ecological solutions. For example, in Lubuskie only 50.2% of companies declare reducing paper printing, and 37.6% reduce energy consumption by ICT equipment, which places this region at the bottom of the list.

It can also be noted that regions such as Małopolska and Lower Silesia, although they do not reach the Warsaw levels, show relatively high rates of implementation of pro-ecological practices. Lower Silesia, on the other hand, is characterized by a 57.4% share of companies limiting paper printing and a 63.4% share of companies taking into account environmental issues when choosing ICT equipment, which may indicate well-developed structures supporting sustainable development and the presence of numerous technology companies that invest in ecological solutions. Northern regions such as Pomerania and West Pomerania are also interesting. In the Pomeranian Voivodeship, the percentage of enterprises returning waste equipment to appropriate collection points is 75.1%, which indicates a very high awareness of ICT equipment recycling. Such practices can be supported by well-developed waste management systems and regional policies that promote environmental protection.

To sum up, the level of implementation of the specified pro-ecological practices in enterprises varies and depends on local economic conditions and the degree of development of technological infrastructure. Regions with a higher level of development, such as the Warsaw Capital Region or Lower Silesia, perform better in implementing sustainable ICT practices, while less developed regions, such as Lubuskie or Mazowiecki Regional, lag behind.

Then, measures of development for the studied regions were calculated and a ranking was made, ordering them in descending order. The results are presented in Table 2.

Table 2.

Ranking according to the measure of development of NUTS-2 regions in the implementation of pro-ecological solutions in the area of the use of ICT equipment

NUTS-2 region	Distance from pattern	Measure of development	Ranking
Warszawski Stołeczny	1.484	0.982	1
Dolnośląskie	4.002	0.953	2
Śląskie	4.181	0.950	3
Pomorskie	4.297	0.949	4
Wielkopolskie	4.839	0.943	5
Małopolskie	5.021	0.941	6
Opolskie	5.078	0.940	7
Zachodniopomorskie	5.087	0.940	8
Warmińsko-mazurskie	5.707	0.932	9
Kujawsko-pomorskie	5.781	0.932	10
Podkarpackie	5.837	0.931	11
Podlaskie	6.412	0.924	12
Łódzkie	6.568	0.922	13
Lubelskie	6.769	0.920	14
Świętokrzyskie	6.895	0.918	15
Mazowiecki Regionalny	7.270	0.914	16
Lubuskie	8.529	0.899	17

Source: own study.

The first place in the ranking is taken by the Warsaw Capital Region, which achieves the highest value of the measure of development (0.982) and the lowest distance from the standard (1.484). The region's high score is in line with its strong economic position, high level of urbanization, and access to resources and technologies to support green activities. Companies

in the region are better able to implement innovative and sustainable practices, which translates into high environmental performance. Lower Silesia and Silesia, occupying the second and third place in the ranking, respectively, are also characterized by high values of the measure of development, amounting to 0.953 and 0.950. These regions are known for their booming industrial and technological sectors, which is conducive to investment in solutions that reduce environmental impact. A strong industrial base in Silesia, combined with an increasing focus on the ecological transition, contributes to achieving relatively high results in the area of sustainable use of ICT. Regions such as Pomerania, Greater Poland and Lesser Poland are at the top of the ranking, with measures of development of 0.949, 0.943 and 0.941 respectively. Pomerania, for example, is well positioned thanks to its well-developed recycling infrastructure and strong commitment to environmental activities supported by regional policy. Wielkopolska and Małopolska also show high activity in the implementation of ecological practices, which may result from the presence of numerous innovative enterprises. At the end of the ranking are the following regions: Mazowiecki Regionalny and Lubuskie, which achieve the lowest measures of development (0.914 and 0.899, respectively) and the highest distances from the standard (7.270 and 8.529). The low results of these regions indicate the need to increase investment in pro-ecological solutions and to raise environmental awareness among local enterprises. The Mazovian Regional Region, despite its proximity to the capital area, shows significant shortcomings in the implementation of sustainable practices.

4. Conclusion

This study provides important information on the spatial differentiation of the implementation of pro-ecological ICT practices in Polish enterprises, broken down by NUTS-2 regions. The main objective of the study was to identify regional differences and rank administrative units in terms of the level of sustainable management of ICT equipment. This goal was achieved through the use of multivariate statistical analysis methods, which allowed comprehensive conclusions to be drawn.

The results indicate that the Warsaw Capital Region is distinguished by the highest level of implementation of pro-ecological solutions, which reflects its developed technological infrastructure and high environmental awareness of enterprises. The Lower Silesia and Silesian regions also achieved high values of the measure of development, which can be linked to dynamically developing industrial sectors and investments in ecological innovations. On the other hand, regions such as Mazowiecki Regionalny and Lubuskie are at the bottom of the ranking, indicating the need to intensify pro-ecological activities and greater support in the field of ecological infrastructure.

The research hypotheses were positively verified. Significant regional differences in the implementation of sustainable practices have been confirmed and it has been shown that a higher level of economic development of the region correlates with more frequent implementation of pro-ecological activities.

However, despite the achievement of the research goal, some limitations can be identified in this study. First, the research involves the use of data from one year, which does not allow for the analysis of long-term trends. In addition, the variables used may not fully reflect the complexity of the phenomenon of implementing pro-ecological practices. Future research should take into account long-term data and additional factors such as regional policies, implementation barriers and environmental awareness. It is also worth considering international comparisons to assess how Polish regions compare to other countries in terms of sustainable management of ICT equipment in enterprises.

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