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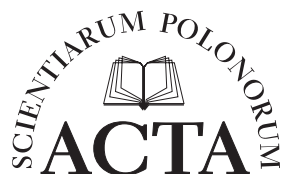
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Yours sincerely

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ARTIFICIAL INTELLIGENCE IN LEARNING AND WORK PRACTICES: URBAN–RURAL DIFFERENCES IN PERCEIVED PRODUCTIVITY AND COMPETITIVENESS

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ABSTRACT

Aim: Artificial intelligence (AI) is increasingly shaping learning processes and work practices, with important implications for productivity and regional competitiveness. However, the benefits of AI adoption may not be evenly distributed across urban and rural contexts. This study examines how individuals living in large cities, small cities, and rural areas perceive and use AI in learning and professional activities, and how they evaluate its economic benefits and associated risks. **Method:** The study is based on an online survey conducted in 2025 in Lithuania, comprising 17 Likert-scale items measuring perceived productivity benefits, learning support, digital skills, the future relevance of AI, and perceived risks. The final sample comprised 120 valid and fully completed responses ($N = 120$). Descriptive statistics were used to summarize response patterns, and pairwise Welch's t-tests were applied to explore differences across residential contexts. **Results:** The results indicate generally positive attitudes toward AI across all groups, particularly regarding overall time-saving, improved decision-making, and enhanced competitiveness. Statistically significant differences were observed only between respondents living in large cities and small cities, with greater concern about potential job displacement. **Conclusions:** Overall, the findings of the sample suggest that while AI is widely perceived as a generally productivity-enhancing tool across regions, place-based disparities in skills and perceptions persist, underscoring the need for targeted training, institutional support, and inclusive digital policies to strengthen balanced regional competitiveness.

Key words: artificial intelligence, labor market, urban–rural differences, digital skills, regional development

JEL codes: O33, R11, J24

INTRODUCTION

Artificial intelligence (AI) is increasingly recognized as a key driver of economic transformation, with significant implications for productivity growth, labor markets, and competitiveness across regions. At the macroeconomic level, AI adoption contributes to productivity gains by automating routine activities, improving data processing and analysis, and sup-

porting more informed and timely decision-making, thereby influencing economic growth and income distribution (Filippucci et al., 2024). Recent research further emphasizes that AI can act as a catalyst for rural economic development by enabling technological upgrading in traditionally lagging sectors such as agriculture, public services, and local administration (Zhu, 2025). These effects are particularly relevant in knowledge-intensive sectors, where AI can enhance

efficiency, reduce operational costs, and partially offset skill shortages. However, the economic benefits of AI are not distributed evenly, raising concerns about spatial inequalities between urban and rural areas.

From a regional development perspective, urban–rural disparities remain a central issue in AI adoption. Research focusing on rural and small-town contexts shows that while enterprises and workers in these areas increasingly recognize the potential economic value of AI, adoption is often constrained by weaker digital infrastructure, limited access to advanced technologies, and shortages of specialized skills (Dowell et al., 2024). Studies on rural AI diffusion indicate that without targeted policy support and infrastructure investment, AI adoption may reinforce rather than reduce existing regional inequalities (Zhu, 2025). As a result, rural economies may face a relative disadvantage in capturing productivity gains from AI compared with large urban centers, where digital ecosystems, innovation networks, and human capital are more developed (Bijalwan et al., 2024). These disparities highlight the importance of understanding AI not only as a technological innovation but also as a factor shaping regional competitiveness.

Education and human capital development play a crucial role in mediating the economic impact of AI across regions. AI-related skills are becoming essential for employability and labor-market resilience, particularly as automation reshapes job tasks and occupational structures. Empirical evidence suggests that AI development can improve the quality of rural employment by expanding access to learning and training opportunities, thereby enhancing workers' job competitiveness, although these effects vary across regions (Li et al., 2025). However, access to AI education and training remains uneven. López Costa (2025) demonstrates that rural schools and training institutions face structural challenges in integrating AI and data literacy into curricula, potentially reinforcing existing skill gaps between urban and rural populations. From an economic standpoint, such gaps may limit the capacity of rural labor markets to adapt to technological change and benefit from AI-driven productivity improvements.

Higher education institutions and training providers are therefore increasingly viewed as key actors in re-

gional economic development. Studies in accounting and management education indicate that meaningful AI integration depends on institutional readiness, curriculum design, and alignment with labor-market needs rather than formal program labels alone (O'Hara et al., 2024). From a managerial and organizational perspective, leadership, policy clarity, and investment in digital infrastructure are critical enablers of effective AI adoption in educational settings (Huma et al., 2025; Shahzad et al., 2025). Where such conditions are absent, AI learning tends to occur informally and unevenly, potentially amplifying urban–rural disparities in digital competence and economic opportunity.

Empirical evidence on student and early-career professional engagement with AI further illustrates these dynamics. Research shows that students widely use AI tools for general learning support, text generation, and data processing, and strongly associate AI with efficiency gains, automation of routine tasks, and improved accuracy – attributes directly linked to productivity enhancement. At the same time, concerns about over-reliance, data security, and the erosion of critical thinking remain salient, reflecting an awareness of the economic and professional risks associated with uncritical AI adoption (Vieriu & Petrea, 2025). Importantly, studies grounded in technology adoption frameworks suggest that perceived usefulness alone is insufficient to ensure effective AI uptake; ease of use, access to training, and opportunities for practical application are equally important determinants (Gaviria Rodríguez et al., 2025).

The literature also reveals a persistent gap between general-purpose AI use and professionally embedded applications that directly influence economic performance. While AI is widely used for generic tasks, its adoption in specialized domains remains limited (Kokina et al., 2025). Evidence from agricultural and rural labor markets indicates that AI can simultaneously displace low- and medium-skilled jobs while creating new opportunities for high-skilled labor, underscoring the importance of skills development and adaptive learning systems (Yang et al., 2025). These challenges may be particularly pronounced in rural and small-town organizations, which often operate with limited resources and lower capacity for technological experimentation.

Taken together, the existing literature highlights both the economic potential of AI to enhance productivity and competitiveness and the structural constraints that shape its uneven diffusion across urban and rural contexts. Recent empirical studies show that AI can support rural industrial revitalization and structural upgrading, particularly in technologically lagging regions, but that outcomes vary significantly across local contexts (Zhao & Yang, 2025). While prior research has examined AI adoption at organizational, sectoral, or educational levels, fewer studies have focused on how individuals in different residential settings perceive and use AI in their everyday learning and work practices. Addressing this gap is critical for understanding whether AI can contribute to more balanced regional development or whether it risks reinforcing existing urban–rural economic disparities. By analyzing AI use, perceived benefits, and learning needs across large cities, small cities, and rural areas, the present study contributes empirical evidence relevant to discussions on inclusive digital transformation and regional economic competitiveness.

Building on the reviewed literature and the identified research gap, this study addresses the following research questions:

- RQ1: How do individuals living in large cities, small cities, and rural areas use artificial intelligence in their learning and work practices, and how do they perceive its effects on productivity and competitiveness?
- RQ2: Are there significant differences between large-city, small-city, and rural residents in their perceptions of AI-related digital skills, learning support, and associated risks?

Answering RQ1, we expect generally positive use and perceptions of AI for learning and working across large cities, small cities, and rural areas, especially regarding time saving, learning support, and competitiveness, with slightly higher perceived benefits and digital skills among large-city residents. Answering RQ2, we expect limited differences between residential groups, with similar assessments of AI-related learning support and risks, but stronger concerns about future job demand among large-city respondents.

AIM AND METHOD

The study employed a quantitative survey design to examine perceptions and use of artificial intelligence (AI) in learning and work contexts across different places of residence. Data were collected in 2025 using a self-administered online questionnaire distributed via institutional networks and social media to respondents living in large cities, small cities, and rural areas in Lithuania. A total of 470 questionnaires were distributed, of which 120 were returned as valid and fully completed, resulting in a final sample size of $N = 120$. The final sample comprised respondents from large cities ($n = 80$; 66.7%), small cities ($n = 28$; 23.3%), and rural areas ($n = 12$; 10.0%).

The survey instrument comprised 17 Likert-scale statements (E1–E17) measuring attitudes toward AI-related productivity benefits, learning support, digital skills, perceived risks, and future relevance. Responses were recorded on a five-point Likert scale ranging from strongly disagree to strongly agree. The questionnaire also included background variables capturing demographic and socioeconomic characteristics, such as gender, education, employment status, income level, and place of residence.

Data from three identical survey versions were merged and harmonized prior to analysis. Descriptive statistics were used to summarize overall response patterns. Mean values and standard deviations were calculated for each survey item by place of residence, and descriptive statistics were used to summarize overall response patterns. To explore differences between groups, pairwise Welch's *t*-tests were conducted, which are appropriate for unequal sample sizes and variances. Although Likert-scale responses are ordinal, parametric tests were applied because the data approximate interval-level measurement and the sample size is sufficient; this approach is commonly accepted in similar studies. Given the exploratory nature of the study and the relatively small rural subsample, the analysis focused on identifying indicative patterns rather than making causal claims; accordingly, *p*-values were not adjusted for multiple comparisons.

RESULTS

The final sample comprised respondents residing predominantly in large cities (66.7%), followed by small cities (23.3%) and rural areas (10.0%). Respondents were in a broadly similar age group across locations, with a mean age of approximately 28.7 years in large cities, 29.4 in small cities, and 30.2 in rural areas, indicating no substantial age differences between groups. In terms of gender, the sample was moderately imbalanced, with women representing a clear majority (around 60–65%), while men accounted for roughly one third of respondents, and a small proportion preferred not to disclose their gender. Most respondents had higher education, with over half holding a bachelor's degree and a substantial share reporting master's-level or equivalent education, while a smaller proportion had vocational or secondary education. Most participants were employed or combined work with studies, indicating strong integration into the labor market. Income levels were distributed across low, medium, and higher brackets, with middle-income respondents forming the largest group, while lower- and higher-income categories were each represented by smaller but meaningful shares. Overall, the sample reflects a relatively well-educated, economically active population with diverse socioeconomic backgrounds, suitable for exploratory analysis of AI-related attitudes across different places of residence.

The results also suggest that the sample consists largely of digitally literate individuals across all residential groups, as reflected in similar levels of self-assessed digital skills (3.48, 3.21, 3.08 on a 1–5 scale for large cities, small cities, and rural areas, respectively) and a consistently high sense of responsibility to improve them (4.25, 3.93, 4.33). Second, the results also suggest a degree of convergence in access to and use of AI tools, as indicated by comparable frequencies of general AI use (4.12, 3.86, 3.65) and learning-related use (3.61, 3.69, 3.41) across all groups.

Overall, the distribution of responses indicates a generally positive, pragmatic attitude toward artificial intelligence across all survey items (Fig. 1). Strong agreement is most evident for statements related to personal digital responsibility (E1), time-saving benefits of AI (E6), the necessity of human control

over AI solutions (E11), and concerns about the potential impact of excessive AI use on critical thinking (E12), indicating both high engagement and reflective caution. Respondents largely agree that AI can enhance competitiveness, improve data analysis and decision-making, increase accuracy, and support learning and professional tasks (E5–E8), although these items also show a notable share of neutral responses, suggesting varying levels of experience or confidence. Perceptions of future relevance and the need for practical AI skills and institutional support (E3, E4, E14, E16) are predominantly positive, highlighting expectations that AI will play an increasingly important role in education and work. At the same time, attitudes toward risks, such as job displacement, privacy, and security concerns (E9, E10), are more mixed, reflecting ambivalence rather than outright opposition. Finally, readiness to continue learning about AI (E13) is high, while confidence in having sufficient digital skills (E15) is more moderate, underscoring the ongoing need for targeted training and support to ensure effective and responsible AI adoption.

The comparison across large cities, small cities, and rural areas reveals broadly similar and generally positive attitudes toward artificial intelligence, with only modest variations between groups (Figs. 2 and 3). As shown in Figure 2, respondents in all three settings reported strong agreement regarding personal responsibility for improving digital skills, the usefulness of AI for saving time, improving data analysis and decision-making, and its growing importance for their field of work. Residents of large cities tended to report slightly higher confidence in their digital skills and somewhat stronger perceptions of AI's analytical and professional benefits, while respondents from rural areas often expressed comparable or even slightly higher readiness to learn more about AI and to acquire practical application skills.

At the same time, as illustrated in Figure 3, attitudes toward potential risks – including job displacement, data privacy concerns, and the need for human oversight – were more moderate and mixed across all groups, with no pronounced divergence by place of residence. Across locations, there was a consistent recognition that AI systems require human control and that excessive reliance on AI may negatively

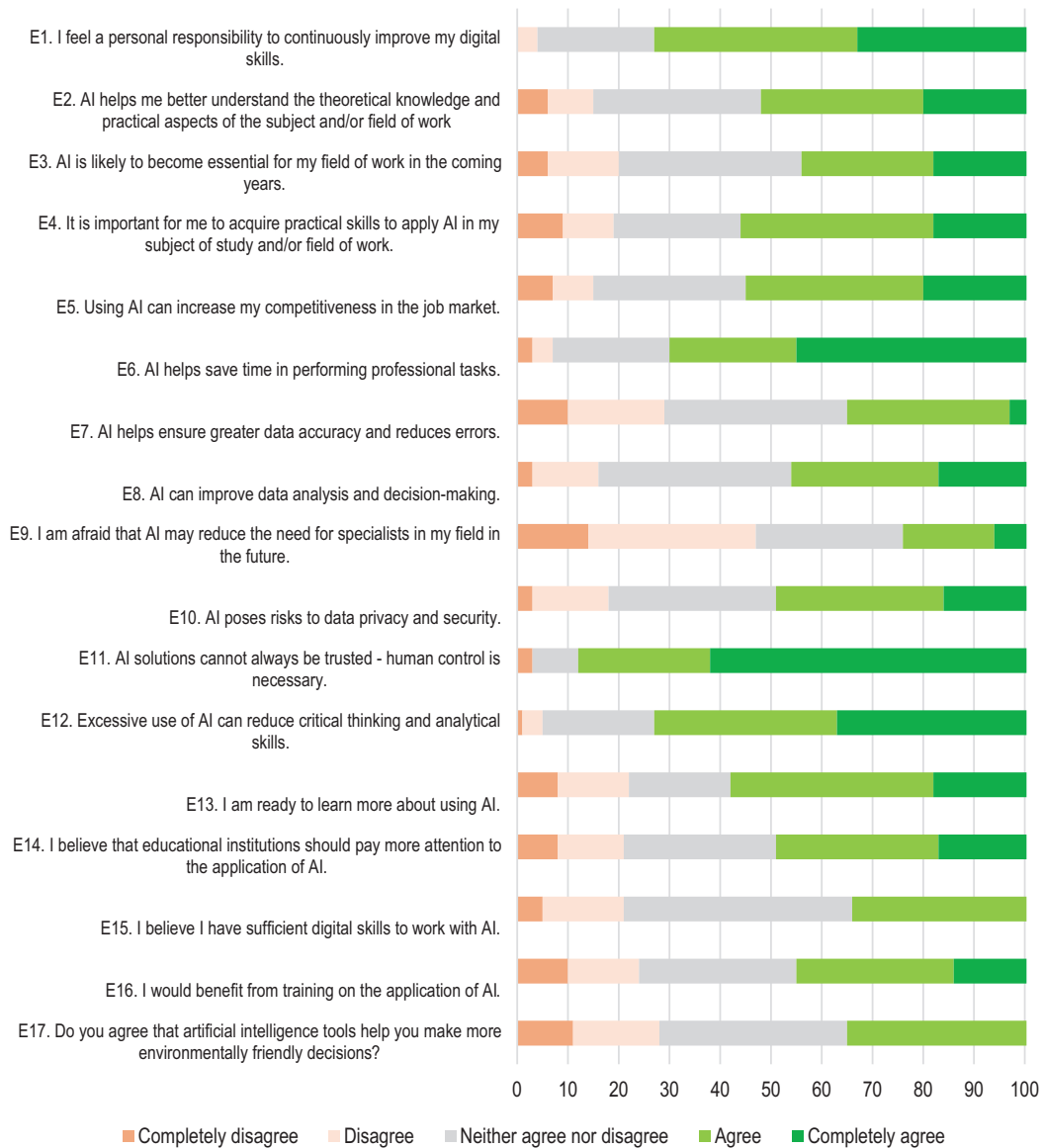


Fig. 1. Five-point scale responses to AI-related attitude statements [%]

Source: authors' calculations.

affect critical thinking, indicating a shared awareness of both benefits and risks. Overall, the results suggest that AI is perceived as increasingly relevant and valuable across urban, small-city, and rural contexts alike, while also highlighting a common need for continued training, institutional support, and responsible implementation regardless of geographic location.

Pairwise Welch's t-tests revealed a statistically significant difference only between large-city and small-city respondents with respect to concerns that artificial intelligence may reduce the future need for specialists in their field (E9; $t = 2.07$, $p = 0.043$, Cohen's $d = 0.44$), with large-city respondents expressing higher levels of concern. No statistically significant

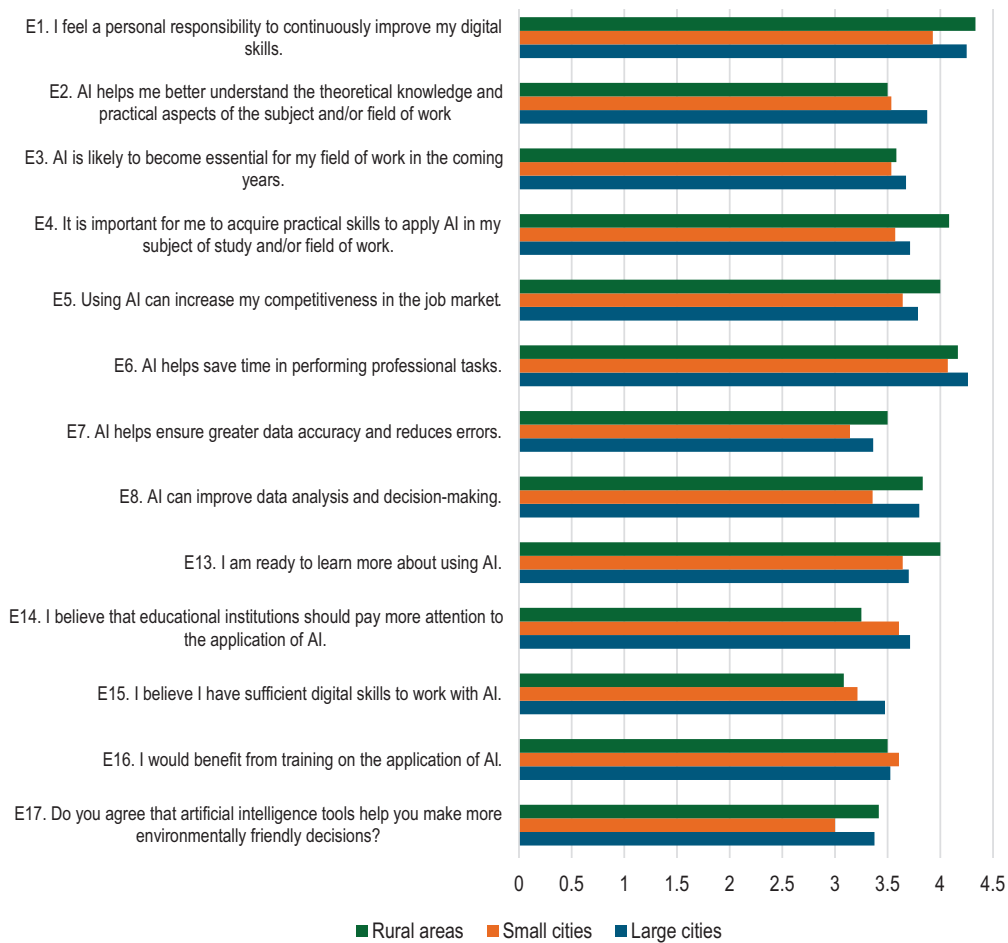


Fig. 2. Mean responses to AI-related benefits and learning aspects by place of residence (large cities, small cities, and rural areas)
Source: authors' calculations.

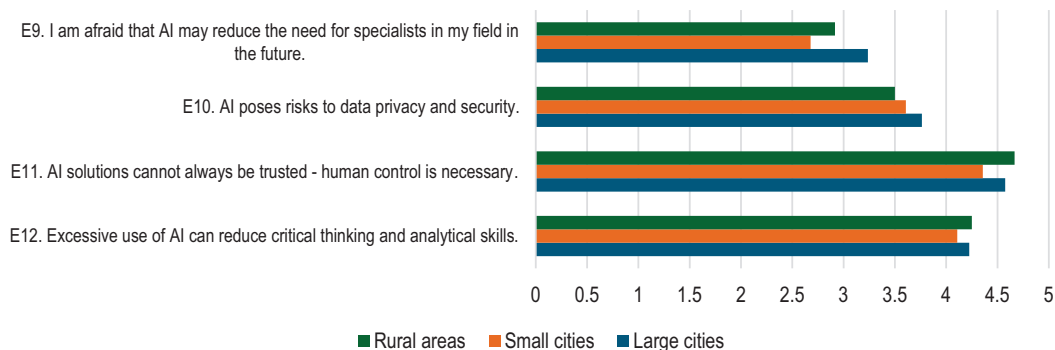


Fig. 3. Mean responses to AI-related risks and concerns by place of residence (large cities, small cities, and rural areas)
Source: authors' calculations.

differences were detected between large-city and small-city respondents in perceived analytical benefits of AI (E8; $t = 1.66$, $p = 0.106$) or self-assessed digital skills (E15; $t = 1.20$, $p = 0.234$). Furthermore, no statistically significant differences were detected between urban and rural respondents or between small-city and rural respondents across any of the examined items (all $p > 0.05$). It should be noted that the rural subsample is relatively small ($n = 12$), which limits statistical power and reduces the likelihood of detecting statistically significant differences involving this group.

DISCUSSION

The findings of this study reinforce existing evidence that artificial intelligence is increasingly perceived as a valuable tool for enhancing productivity, learning efficiency, and decision-making, while also revealing important spatial nuances in these perceptions. Overall positive attitudes toward AI's time-saving and analytical benefits align with macro-level evidence that AI contributes to productivity growth and efficiency gains across sectors (Filippucci et al., 2024). Respondents' strong support for AI-assisted decision-making and competitiveness suggests that AI is increasingly viewed as an economic resource rather than merely a technological novelty.

At the same time, the results highlight subtle yet meaningful differences between respondents living in large cities and those in small cities. Urban respondents reported higher confidence in their digital skills and stronger agreement with AI's analytical benefits, consistent with prior research showing that urban environments tend to offer greater access to digital infrastructure, training opportunities, and innovation ecosystems (Dowell et al., 2024). These findings suggest that spatial context continues to shape the capacity to fully leverage AI, even when overall attitudes are broadly positive.

Concerns related to job displacement, data security, and over-reliance on AI were evident across all residential contexts, supporting earlier work that emphasizes the need for human oversight, ethical safeguards, and critical engagement with AI technologies (Vieriu & Petrea, 2025). Importantly, these concerns did not negate respondents' willingness to adopt AI, indicating

a balanced perspective that recognizes both economic benefits and risks. This pattern is consistent with studies showing that perceived usefulness must be complemented by trust, usability, and institutional support to sustain meaningful adoption (Gaviria Rodríguez et al., 2025).

Finally, the relatively similar perceptions observed between small-city and rural respondents may reflect shared structural conditions, such as limited access to formal AI training and fewer organizational resources, as highlighted in prior research on rural education and enterprise contexts (Dowell et al., 2024; López Costa, 2025). From a policy and regional development perspective, these findings underscore the importance of targeted investments in digital infrastructure, AI-related skills development, and institutional support mechanisms to ensure that AI contributes to balanced regional competitiveness rather than reinforcing existing urban–rural disparities.

CONCLUSIONS

This study analyzed the use of artificial intelligence in learning and work practices and examined differences in perceived productivity, competitiveness, skills, and risks across large-city, small-city, and rural contexts. The results indicate generally positive attitudes toward AI in all residential groups, particularly regarding its potential to support learning, save time, and improve data accuracy. Empirical evidence shows that differences between residential groups are limited, with a statistically significant difference identified only between large-city and small-city respondents in concerns about the future demand for specialists.

The absence of significant differences between urban and rural respondents across most dimensions suggests a relatively homogeneous diffusion of general-purpose AI tools and perceptions, regardless of place of residence. These findings imply that policies and educational initiatives aimed at enhancing AI-related skills should address learners and workers across all regions rather than focusing exclusively on urban or rural areas.

Several limitations should be acknowledged. The study relies on self-reported perceptions rather than objective measures of productivity, and the rural subsample is relatively small, which may

limit statistical power. As participation was voluntary and self-selected, the sample may be biased toward more digitally engaged individuals; accordingly, the findings should be interpreted as exploratory and not fully representative of the broader population. In addition, the cross-sectional design does not allow for causal interpretation or analysis of changes over time. Future research could build on these findings by using longitudinal data, larger and more balanced samples, and by examining sector-specific applications of AI to better understand its impact on productivity and competitiveness across regions.

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SZTUCZNA INTELIGENCJA W PROCESACH UCZENIA SIĘ I PRAKTYKACH PRACY: RÓŻNICE MIEJSKO-WIEJSKIE W POSTRZEGANEJ PRODUKTYWNOŚCI I KONKURENCYJNOŚCI

STRESZCZENIE

Cel: Sztuczna inteligencja (AI) w coraz większym stopniu kształtuje procesy uczenia się oraz praktyki zawodowe, wywierając istotny wpływ na produktywność i konkurencyjność regionalną. Korzyści wynikające z wdrażania AI mogą jednak nie być równomiernie rozłożone pomiędzy obszary miejskie i wiejskie. Celem badania było wskazanie, jak mieszkańcy dużych miast, małych miast oraz obszarów wiejskich postrzegają i wykorzystują AI w procesach uczenia się oraz działalności zawodowej, a także jak oceniają jej korzyści ekonomiczne i związane z nią ryzyko. **Metoda:** Badanie przeprowadzono w 2025 roku na Litwie z użyciem kwestionariusza ankiety online, obejmującego 17 pozycji w skali Likerta, mierzących postrzegane korzyści produktywnościowe, wsparcie procesu uczenia się, kompetencje cyfrowe, przyszłe znaczenie AI oraz postrzegane ryzyko. Ostateczna próba badawcza obejmowała 120 poprawnie i kompletnie wypełnionych kwestionariuszy ($N = 120$). Do podsumowania wzorców odpowiedzi zastosowano statystyki opisowe, do analizy różnic pomiędzy typami miejsca zamieszkania wykorzystano zaś test t Welcha dla prób niezależnych. **Wyniki:** Wykazano empirycznie pozytywne postawy wobec AI we wszystkich badanych grupach, szczególnie w odniesieniu do oszczędności czasu, poprawy jakości podejmowania decyzji oraz wzrostu konkurencyjności. Statystycznie istotne różnice zaobserwowano jedynie pomiędzy respondentami zamieszkującymi duże miasta i małe miasta, przy czym mieszkańcy dużych miast wykazywali większe obawy dotyczące potencjalnego wypierania pracowników przez AI. **Wnioski:** Uzyskane wyniki w badanej próbie sugerują, że AI jest postrzegana jako narzędzie zwiększające produktywność niezależnie od regionu, jednak nadal występują przestrzennie zróżnicowane dysproporcje w zakresie kompetencji i percepcji. Podkreśla to potrzebę wdrażania ukierunkowanych szkoleń, wsparcia instytucjonalnego oraz inkluzywnych polityk cyfrowych sprzyjających wzmocnieniu zrównoważonej konkurencyjności regionalnej.

Słowa kluczowe: sztuczna inteligencja, rynek pracy, różnice miejsko-wiejskie, kompetencje cyfrowe, rozwój regionalny

EFFECT OF DIGITAL TECHNOLOGIES ON THE PRODUCTIVITY OF RICE FARMERS IN KWARA STATE, NIGERIA

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ABSTRACT

Aim: Rice production in Nigeria falls short of domestic demand, increasing reliance on imports. Digital technologies could enhance productivity through improved information sharing, planning, and decision-making, yet adoption among rice farmers is limited and underexplored. This study examines the effect of digital technologies on rice productivity in Kwara State, Nigeria. **Methods:** Primary data were collected from 151 farmers using a three-stage sampling procedure. Analysis employed descriptive statistics, regression models, sigma scoring, and Likert scales. **Results:** Results indicate mobile phones are the most widely adopted digital tool; their use, particularly for communication with extension agents, was significantly associated with higher rice productivity. Key determinants of adoption include age, household size, digital awareness, farming experience, and access to finance. Despite its benefits, adoption is constrained by the high cost of digital technologies, poor network coverage, unreliable power supply, limited access to extension services, and poor access to credit. **Conclusions:** The study concludes that digital technologies are associated with higher rice productivity, but their transformative potential is curtailed by infrastructural and institutional limitations. Policy recommendations include strengthening digital literacy, expanding rural network coverage, and improving access to credit to promote wider adoption, increase productivity, and support food security and sustainable agricultural development in Nigeria.

Key words: productivity, sigma scoring approach, the logit regression model, ordinary least square regression, digital technology, rice farmers, Kwara State

JEL codes: O33, Q12, Q16

INTRODUCTION

Agriculture remains central to Nigeria's economy and food security. It supports rural livelihoods, contributes substantially to GDP, accounting for roughly 23% to 24.45% between 2016 and 2023, and employs about

34% of the workforce, thereby underpinning economic growth (National Bureau of Statistics [NBS], 2023; World Bank, 2025a; World Bank, 2025b). Despite abundant arable land and natural resources (African Development Bank [ADB], 2023), Nigeria's population has grown rapidly, from approximately 213.9 million

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in 2020 to about 237.5 million in 2025, with an annual growth rate of about 2.1% in 2024 (United Nations [UN], 2025; United Nations Population Fund [UNFPA], 2025; World Bank, 2025c). This rapid growth has made Nigeria the most populous country in Africa and has intensified food demand. However, domestic rice production has lagged behind demand, necessitating substantial imports and exposing the economy to foreign exchange pressures (Federal Ministry of Agriculture and Rural Development [FMARD], 2016; United States Department of Agriculture Foreign Agricultural Service [USDA FAS], 2023).

Oryza sativa (rice) is a major staple consumed by over half of the world's population, including more than 150 million people in Africa (Opeyemi et al., 2015; Fang et al., 2021). In Nigeria, rice is grown across most agro-ecological zones and remains central to the diet, but domestic production still falls short of demand, leading to substantial imports (Banjoko et al., 2016; Olasehinde et al., 2022). In 2016, local output was 2.3 million metric tons while national consumption was 6.3 million metric tons, leaving a shortfall of about 4.0 million tons that had to be met through imports; between 2012 and 2015, the government spent over USD 2 billion on rice imports (Premium Times, 2015; FMARD, 2016). More recently, in the 2023/24 marketing year, Nigeria produced approximately 5.61 million metric tons of milled rice against a forecast consumption of 7.8 million tons, leaving a projected import gap of about 2.19 million tons (USDA FAS, 2023). Meeting rising food demand will therefore require marked improvements in agricultural productivity rather than mere expansion of cultivated area (Trendov et al., 2019; Tavershima et al., 2022). At the same time, the associated social and environmental repercussions must be carefully evaluated (Connolly-Boutin & Smit, 2016). The digital revolution in agriculture has opened up new ways for this transformation to be achieved.

Digital technologies, particularly mobile-based information services, decision-support applications, and precision tools, are widely touted as possible levers to raise productivity by improving access to mar-

ket, weather, input, and advisory information, and by enabling better planning, logistics, and procurement (Arunachalam et al., 2018; World Economic Forum [WEF], 2020). They also support sustainability by optimizing resource use, reducing greenhouse gas emissions, and promoting efficiency, equity, and collaboration across the food chain (WEF, 2022). Platforms like GeoFarmer enable timely feedback, performance monitoring, and knowledge sharing, enhancing productivity and reducing risks for rural communities (Eitzinger et al., 2019).

However, the evidence on whether and how digital technology adoption translates into measurable productivity gains for smallholder rice producers in Nigeria is limited. Most empirical work has focused on awareness, diffusion patterns, or single technologies (e.g., mobile phones) rather than estimating the causal effect of digital adoption on farm productivity at the crop (rice) level. This empirical gap weakens the evidence base available to policymakers seeking to design interventions that could increase domestic rice output and reduce import dependence.

This study addresses that gap by empirically examining the relationship between digital technology adoption and rice productivity among smallholder rice farmers in Kwara State, Nigeria. Using primary farm-level data, the study identifies the digital technologies used by rice farmers, measures adoption intensity, i.e., the extent of farm-level uptake of digital technologies, assesses determinants of adoption, estimates the effect of adoption on rice productivity, and identifies the constraints to rice farmers' utilization of digital technologies in the study area. The results are intended to inform targeted policies to scale up effective digital solutions in Nigeria's rice sector.

Research questions:

1. What digital technologies are used by rice farmers in Kwara State, and at what intensity?
2. What are the determinants of digital technology adoption?
3. What is the effect of digital technology adoption on rice productivity?
4. What constraints limit rice farmers' utilization of digital technologies?

LITERATURE REVIEW

Digitalization research in agriculture draws on diffusion/adoption and sustainable-agriculture frameworks and uses a wide range of methods, from large-scale econometric analyses to micro-level regressions and qualitative case studies. Empirical work includes Liu and Liu (2023), who analyzed panel data from 276 prefecture-level (and higher) Chinese towns between 2005 and 2020 to assess the effects of digital technologies on sustainable agriculture (SA). They found that digitalization significantly improves SA and its subsystems, with larger effects in peripheral towns and in China's more developed eastern region. At the micro-level, Zeng et al. (2024) used Probit models and the KHB mediation technique on China Land Economic Survey (CLES) data to show that greater digital access raises the probability of land transfer. The probability of land transfer increased by 6.2% for every unit increase in digital technology accessibility.

Addison et al. (2024) examined the causes of agricultural digitalization (AD) and its effects on smallholder farmers' lives in rural Ghana. To address endogeneity, they combined probit and tobit estimators with inverse-probability weighting and regression adjustment to investigate both the determinants and the intensity of digital-technology adoption. They found that higher education, positive attitudes toward digitalization, membership in groups and cooperatives, more employed household members, and access to reliable internet, mobile money, and energy significantly increased the use of digital technology in agricultural operations. The study also reported a positive association between AD and smallholders' perceived improvements in livelihoods and household well-being.

Mhlanga and Ndhlovu (2023) reviewed the literature on digitalization in African agriculture, assessing its extent, effects on productivity and sustainability, key drivers and barriers, and policy options to accelerate uptake. They found widespread variation across the continent and highlighted several important issues, such as connectivity, affordability, energy, skills, and institutional gaps that require attention. In qualitative research, Fourati-Jamoussi et al. (2023) assessed

the effect of digital technologies like vineyard robots (Vitirover) and mapping drones (Airinov) on farm business models. Their findings showed that farmers adopt or develop digital tools primarily to solve practical problems such as improving production conditions, entering new markets, or adding value. Farmers who used these technologies displayed diverse skills, curiosity, and flexibility in adapting business models. Jarial and Sachan (2021), in an analysis of agricultural extension, observed a lack of gender responsiveness in Extension Advisory Services, particularly for women farmers. They emphasized that unprepared farmers, especially women, may struggle to adjust to digital agriculture without tailored support, calling for gender-sensitive strategies in digital innovation.

Furthermore, several studies find that digital technologies can improve agricultural performance. They play a vital role in processing and disseminating agricultural information and in improving supply chain operations (Arunachalam et al., 2018). Digital tools can enable a more circular economy and improve efficiency, equity, and environmental sustainability in the food chain. Large-scale country analyses show positive links between digitalization and indicators of sustainable agriculture (Liu & Liu, 2023). Digital technologies can be used to measure and track sustainability progress, optimize resource use, minimize greenhouse gas emissions, and drive innovation and collaboration (WEF, 2022).

Around the world, a plethora of smartphone applications promote agriculture on many levels. A variety of technologies, from simple offline farmer advisory tools to intricate precision agriculture systems, are revolutionizing the agricultural sector when farmers have access to real-time, actionable information. These tools help reduce economic disparities and generate opportunities for rural communities (WEF, 2020). Mobile phones give farmers access to bank accounts, market prices, weather forecasts, and extension contacts; platforms such as GeoFarmer enable real-time knowledge exchange among farmers, experts, and practitioners, reducing risks, increasing production, and improving livelihoods (Eitzinger et al., 2019). The mobile phone has surpassed all other technologies in terms of public acceptability (Nakasone & Torero, 2016; Baumüller,

included both closed and open-ended questions. Secondary data were sourced from textbooks, journal articles, online databases, reports, and previous studies.

The study focused on rice farmers in Kwara State, Nigeria. A three-stage selection technique was used to select 151 respondents. First, two rice-producing local government areas (LGAs) were purposively selected. Ten communities were selected at random from these LGAs for the second stage. Finally, 151 rice farmers were randomly selected from the ten communities. Only fully completed questionnaires were retained for data entry and analysis, resulting in a final analytical sample of 151 observations. A summary of the sample procedure is presented in Table 1.

Table 1. An overview of the methods used in sampling

Local government areas	Community	Number of respondents
Edu	Bokungi	15
	Patidzuru	15
	Abu Efu	15
	Ndamaraki	15
	Takogabi	16
Patigi	Lalagi	15
	Sakpefu	15
	Dzwajiwo	15
	Godiwa	15
	Edogi-Kpansanko	15
Total = 2	10	151

Source: authors' research.

All returned questionnaires were checked for completeness, and only fully completed questionnaires ($N = 151$) with complete information on all variables used in the models were retained for analysis. No further treatment of missing data was required. Data entry was performed in Microsoft Excel, and descriptive statistics and econometric analyses were conducted using Stata.

Data was analyzed using methods appropriate to the study objectives. Descriptive statistics, in-

cluding frequency distribution tables and measures of central tendency, were used to describe respondents' socioeconomic characteristics and to identify the digital technologies used. The sigma scoring system measured the level of adoption of digital technologies, while binary logit regression and ordinary least squares regressions, along with the Likert-type scale, were used for further analysis. Given the cross-sectional and observational nature of the data, estimated relationships reflect statistical associations and should not be interpreted as causal effects.

Sigma scoring method

The level of adoption of digital technologies at the farm level among rice farmers in the research area was evaluated using the sigma scoring technique, following the approach described by Agbamu (2006). The method was adopted because it standardizes frequency counts and percentages into normalized scores, thereby providing information on the relative level and intensity of adoption beyond simple adoption rates. This approach has also been applied in previous agricultural adoption studies (Ovwigho, 2013; Adejoh et al., 2017). Steps for applying this technique are as follows:

- Step 1: Determine the proportion of farmers using the digital technologies: $\{(\text{number of farmers utilizing digital technologies} / \text{total number of responders}) \times 100\} = A\%$.
- Step 2: Take the percentage ($A\%$), divide it by two, and deduct the result from 100: $100 - (A\% / 2) = B\%$.
- Step 3: Get the sigma distance (X) by checking $B\%$ in the statistical table of normal deviates.
- Step 4: Add a constant figure of two (2) to the value of the sigma distance and multiply the result by the same constant: $(X + 2) \times 2 = Y$.
- Step 5: The correct sigma score would be 10 minus the outcome (Y), as the sigma technique assigns weight on a 10-point scale in the reverse direction: $10 - Y = Z$.

Decision rule: The adoption of digital technology was judged to be at a low level if the mean score (Z) was less than 5.

Logit regression

The factors influencing rice farmers' usage of digital technologies in the study area were analyzed using logit regression. Logistic regression was used to estimate the probability that rice farmers adopt digital technology as a function of the independent parameters in the model.

Let Q_i be a binary indicator of adoption ($Q_i = 1$ if farmer i used digital technology for rice production and $Q_i = 0$ otherwise). We model the probability of adoption as:

$$P_i = P_r(Q_i = 1|X_i) \quad (1)$$

and estimate the canonical logit specification:

$$\text{logit}(P_i) = \ln \left(\frac{P_i}{1 - P_i} \right) = \beta_0 + X_i^T \beta \quad (2)$$

$$\text{Equivalently, } p_i = \frac{\exp(\beta_0 + X_i^T \beta)}{1 + \exp(\beta_0 + X_i^T \beta)}$$

where:

P_i – probability that the farmer i adopts a digital technology,

β_0 – intercept or constant,

β – vector of coefficients on the explanatory variables X_i ,

X_i – vector of independent variables,

$\left(\frac{P_i}{1 - P_i} \right)$ – odds of adoption (probability of adopting divided by probability of not adopting).

Dependent variable $Q = 1$ for usage of digital technologies for rice production and 0 otherwise.

The independent/explanatory variables are:

- X_1 – farmers' age [years],
- X_2 – income [NGN],
- X_3 – access to credit (1 means access and 0 otherwise),
- X_4 – level of education [years],
- X_5 – awareness of digital technologies (1 means aware and 0 otherwise),
- X_6 – size of the household (category number according to number of people in household),
- X_7 – years of farming experience.

Ordinary least squares regression

The effect of digital technologies on the productivity of rice farmers in the research area was analyzed using ordinary least squares regression (OLS) analysis. The dependent variable used in the regression was an output-variable-cost ratio, used as a productivity proxy, defined as:

$$Y = \frac{A}{TVC}$$

where:

Y – output-variable-cost ratio (productivity index),

A – value of rice output [NGN] per farmer,

TVC – total variable cost [NGN], computed

$TVC = \sum P_i X_i$, with P_i denoting the unit price of the i -th variable input and X_i its quantity.

The regression model is $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_6 X_6$.

Independent variables are:

- X_1 – communication with extension agent via mobile phones (1 means yes, 0 no),
- X_2 – frequency of usage of digital technology in days/week,
- X_3 – purpose of usage of digital technology (1 means rice production, 0 others),
- X_4 – age of farmers [years],
- X_5 – number of network access/usage per farmer,
- X_6 – educational level of the farmer [years of schooling].

Likert scale analysis

The constraints preventing rice farmers in the study areas from embracing digital technology were rated using a Likert scale. Using a four-point rating scale technique, the mean, frequency, and percentage were calculated. The scoring mechanism for the four-point rating was as follows:

- strongly agree (SA) = 4,
- agree (A) = 3,
- disagree (D) = 2,
- strongly disagree (SD) = 1.

Based on a four-point rating system, the mean score of the respondents was determined as follows: $4 + 3 + 2 + 1 = 10$, $10/4 = 2.50$, the threshold point.

Variables with mean values of 2.50 and above were regarded as constraints for rice farmers in the research area, with a threshold criterion of 2.50 being employed for decision-making. Conversely, variables with mean values below the 2.50 threshold value were found to be unrelated to rice farming growth in the research area.

In addition, multicollinearity was assessed using the variance inflation factor (VIF) for all regression models, and the results indicated that multicollinearity was not a concern among the explanatory variables. All VIF values were below 5.

RESULTS AND DISCUSSION

Rice farmers' socio-economic features

Most respondents (39.74%) were aged 20–30, with a mean age of 36, indicating that a sizable portion of respondents in their middle years were engaged in rice farming. Nearly all respondents were male (99.34%), which might suggest that males dominate rice farming. This is consistent with Chekene and Chancellor (2015), who reported that most rice growers in Nigeria are men. However, this finding must be interpreted with caution. The high male representation in the sample may also reflect response bias, with men more likely to participate in the survey, rather than fully excluding the role of women in production. Men often serve as household heads and landowners, making them the visible decision-makers and primary respondents, while women may have been less available or less approached during the interview. Kolawole et al. (2012) also noted that women complement men's roles and are major contributors to rice production, even if underrepresented in surveys.

A large share of respondents (82.12%) was married, which aligns with Henri-Ukoha et al. (2015), who found that married individuals are more engaged in farming activities. This likely explains why children were available for domestic employment. The prevalence of married farmers among the respondents may be linked to the desire to care for their families. Household sizes were relatively large, with the modal household comprising 6–10 persons (45.70%) and a mean size of 7, which enabled considerable family labor.

This makes it possible for everyone in the family to help with the rice farming, potentially reducing the need for paid labor. Larger households using family labor were also found to improve the adoption of agricultural technologies (Ehiakpor et al., 2019).

The statistics also showed that 98% of the respondents had at least some formal education, with 60% attaining university education, 30.46% having secondary education, and about 7% having primary education. The average number of years of formal education was 13.34 years, suggesting that most respondents were educated and possessed a high level of comprehension regarding the problems involved in transmitting information using mobile phones. This supports Kolawole et al. (2012) and Paltasingh and Goyari (2018), who found that farmers' literacy enhanced the pace at which new technology is implemented. Education, therefore, likely strengthens farmers' ability to implement practices that increase yields and minimize environmental risks.

Farming was the main occupation for 97.35% of respondents, while only 2.65% were civil servants. This indicates that the great majority of respondents rely considerably on farming as their main source of income. 88.74% had been engaged in farming for ten years or more, 63.58% had 10–20 years' rice farming experience, and 21.85% had more than 20 years, with an average of 17.43 years in rice production. The degree of productivity on farms can be enhanced by experienced farmers (Adeagbo et al., 2021). In terms of landholding, 54.30% cultivated between 6 ha and 10 ha, suggesting small- to medium-scale farming, consistent with Sodiya and Oyediran (2014), who found that most Nigerian rural farmers live subsistence-level lives.

Approximately 55.63% of respondents belonged to cooperatives or farmer groups, a form of social capital that can improve access to inputs and information (Ogunleye et al., 2021). Regarding extension services, 69.54% of respondents reported contacting extension agents at least once during the most recent farming season, while 30.46% did not; interaction with extension agents and access to timely information were reported to help adjust farming practices and improve productivity.

Digital technologies used by rice farmers and how they are used

Table 2 lists the digital technologies rice farmers employ during the production process. Nearly all respondents (97.35%) used mobile phones, while very few owned computers (1.99%) or tablets (1.99%), and none reported using drones. This overwhelming reliance on mobile phones reflects their affordability and multifunctional role in everyday farming activities. This finding is consistent with previous studies, which highlight the dominant role of mobile phones in agricultural communication and information access. For example, Nzonzo and Mogambi (2016) reported that mobile phones (45.8%) were the most helpful ICT among rice farmers, followed by radio (26.0%), mobile phones/TV/mobile phones (20.8%), and PCs and the Internet (7.3%). Okoedo-Okojie and Omoregbee (2012) similarly found that farmers mainly use global system for mobile communications (GSM) phones, while personal computers (PCs), email, and the internet were used sparingly. Chhachhar et al. (2014) and Sennuga et al. (2020) also reported that mobile phones, radio, and television are channels for agricultural information. The near-universal ownership of phones among respondents highlights mobile devices as the most accessible and affordable entry point into digital agriculture for smallholder farm-

ers. Unlike more capital-intensive technologies such as drones or computers, phones provide low-cost access to market prices, weather forecasts, and extension services.

Table 2. Digital technologies used by rice farmers

Types of digital technology used	Frequency	Share [%]
Mobile phones	147	97.35
Computers	3	1.99
Tablets	3	1.99
Drones	0	0.00
Total	151	100.00

Source: authors' research.

As shown in Figure 2, Android smartphones were the most common (43.05%), followed by common phones; these are basic/feature phones that support call/SMS but lack browsing capability (33.77%). 22.52% reported using both Android and common phones, while only 0.66% combined Android and iPhone usage. Together, about two-thirds of respondents (66.23%) had access to internet-enabled devices, yet a substantial proportion still relied on non-internet feature phones. This mixed-device reality matters

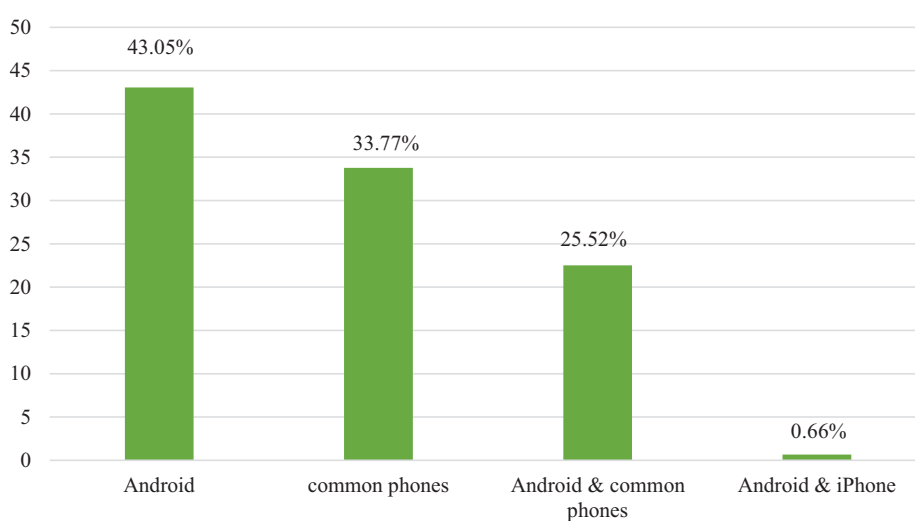


Fig. 2. Mobile phones used by rice farmers ($N = 151$)

Source: authors' research.

because internet access enables advanced agricultural applications, mobile banking, and e-extension services beyond simple SMS or voice communication. Therefore, digital interventions should be device-inclusive: app-based services for smartphone users and SMS/USSD or call-based services for common-phone users. This finding underlines the need to design inclusive platforms that work across device types rather than assuming universal smartphone adoption.

Table 3 presents the number of years the respondents had been using mobile phones. Most had long-term usage, with 44.37% using phones for 6–10 years, 39.07% for over 10 years, and only 17% for 1–5 years, giving an overall mean of 11.33 years. This shows that farmers in the study area are not new to mobile technologies and already possess digital familiarity, which supports a higher potential for technology adoption.

Table 3. Mobile phone usage by rice farmers ($N = 151$)

Mobile phone usage [years]	Frequency	Share [%]	Mean
1–5	25	16.56	11.33
6–10	67	44.37	
11–15	36	23.84	
>15	23	15.23	
Total	151	100	

Source: authors' research.

Questions were asked about their spending pattern, and it showed that 54% of farmers spent between NGN 3,000 and NGN 4,000 monthly on internet services, while 8.61% spent less than NGN 3,000, and 3.97% spent more than NGN 4,000. Most internet users (83%) accessed 3G services, 16% used 4G, and less than 1% used E-internet, with 96% reporting daily use. Despite this high level of connectivity, only a limited proportion applied internet services directly to rice production. This reflects a key gap between access and productive utilization. While familiarity with phones might reduce adoption barriers, turning access into productive use requires targeted capacity building and context-relevant applications.

Farmers reported using mobile phones primarily for calls and SMS, as well as for accessing agricultural information. Key areas of information search included pest and disease control, weather forecasts, improved rice varieties, input availability, credit facilities, market prices, and new cultivation methods. High usage rates were reported for contacting extension agents (70.2%), marketing (94.0%), and farmer-to-farmer communication (98.0%), showing that mobile phones are already integrated into some essential agricultural functions. Some farmers also employed PCs, tablets, or laptops to interact with extension agents (6.62%), other farmers (7.95%), and buyers (7.95%). However, more advanced digital tools and internet-enabled services (e.g., mobile advisory apps, e-extension platforms) remain underutilized, indicating that interventions should prioritize practical, task-oriented tools that align with farmers' needs and device types and encourage the usage of more advanced tools/internet-enabled services.

These findings align with Malsha et al. (2011), who showed that ICT tools were widely used to obtain information on new growing techniques, pest and disease management, and agrochemicals. Similarly, Nzonzo and Mogambi (2016) found that ICTs such as mobile phones, televisions, radios, the Internet, and computers were used to gather information on paddy seed varieties, costs, pests and diseases that affect paddy and the necessary control measures, planting and management techniques, and market opportunities.

Farm level of adoption and uptake of digital technologies

The findings in Table 4 indicate that mobile phones are the most widely adopted digital tool among rice farmers in the study area (sigma score of 5.94), which reflects a high level of adoption and a relatively high intensity of uptake. In contrast, the use of computers, tablets, and drones remains limited, with adoption scores below 5, indicating a low level of adoption. This pattern likely reflects the relatively high awareness of mobile phone applications in agricultural activities. Awareness and knowledge are essential precursors to adoption, as they stimulate farmers' interest

in new technologies and enhance their capacity to use and apply them effectively.

Table 4. Adoption level of digital technologies among the rice farmers ($N = 151$)

Digital technology	Frequency	Share [%]	Sigma score	Remark
Mobile phones	147	97	5.94	High
Computers	3	2	1.34	Low
Tablets	3	2	1.34	Low
Drones	0	0	0.00	Low

Source: authors' research.

These results align with Mwangi and Kariuki (2015), who found that farmers are more likely to adopt technologies they are familiar with or have been informed about. Similarly, Agbamu (2006) noted that access to high-quality information plays a critical role in the uptake of agricultural innovations. The widespread use of mobile phones may also be linked to their role in facilitating communication with extension agents, who provide farmers with timely advice on the availability, benefits, and practical use of improved technologies. Overall, while basic digital tools like mobile phones are being embraced, the low adoption of more advanced technologies highlights significant opportunities to further enhance rice productivity through broader digital technology use.

Determinant of digital technology usage among rice farmers

Findings from the logit regression model used to evaluate the factors influencing rice farmers' usage of digital technology are provided in Table 5. The age, household size, access to credit, digital awareness, and rice farming experience of the respondent substantially affect the decision to apply digital technology.

The coefficient on age was negative and significant at the 1% level. In logit terms, each additional year of age was associated with a 0.177 decrease in the log-odds of adoption, equivalent to about a 16% reduction in the odds of adopting digital technology [$\exp(-0.177) \approx 0.84$], holding other factors constant. In plain terms, older farmers in our sample were less likely to adopt digital tools than younger farmers. This likely reflects differences in digital literacy, prior expo-

sure, and risk preferences. Younger farmers tend to be more familiar with mobile and internet technologies, more comfortable learning new interfaces, and more willing to experiment with digital tools in the process of rice farming operations. This lowers perceived complexity and raises perceived usefulness. These patterns align with diffusion of innovation and technology-acceptance theories, in which perceived ease of use and perceived usefulness accelerate adoption (Davis, 1989; Rogers, 2003).

This is also consistent with the results of Masuka et al. (2016), who discovered that younger farmers employed mobile technology more frequently than their older counterparts ($p < 0.05$). Similarly, the study by Ma et al. (2023) discovered that age had a negative effect on farmers' smartphone usage. In particular, the likelihood of smartphone use drops by 1.3% for every extra year of age, implying that mobile technologies were more likely to be adopted by younger farmers. In addition, Michels et al. (2020) and Michels and Musshoff (2022) noted that older farmers were less likely to use smartphones since they have lower levels of digital literacy. They suggested that younger farmers were more inclined to adopt digital technologies earlier since they have been exposed to them from an early age. Oladimeji et al. (2013) stated that labor productivity was proportional to age when all other parameters were maintained constant. They noted that there was a presumption that younger individuals were more receptive to adopting new technology to enhance productivity, whereas elderly people tended to cling to traditional production procedures. These studies support the results of the current research, which also found that younger farmers were more inclined to adopt mobile technologies for agricultural purposes. The generation in which improved technologies are introduced and adopted tends to understand and utilize them more effectively.

Furthermore, household size was significant and negative ($\beta = -0.408, p < 0.05$), suggesting that larger households were less likely to adopt digital technologies. This may be because farmers had a lot of dependents to feed; hence, fewer disposable resources to spend on devices, data, or other adoption costs. Adoption often requires an upfront investment (device, data, training), and households with

Table 5. Determinant of digital technology usage among rice farmers ($N = 151$) (logit regression)

Variable	Coefficient β	SE	p	Odds ratio [$OR = \exp(\beta)$]
Age	-0.177***	0.061	0.004	0.838
Size of households	-0.408**	0.166	0.014	0.665
Income from rice farming	-5.270	0.783	0.969	0.005
Access to credit	2.337**	0.929	0.012	10.346
Level of education	0.219	0.205	0.283	1.246
Awareness of digital technologies	2.131***	0.804	0.008	8.423
Farm size	0.010	0.179	0.954	1.107
Rice farming experience	0.144**	0.070	0.039	1.155
Constant	2.082	3.489	0.551	8.019

McFadden pseudo $R^2 = 0.687$; log likelihood = -26.622; LLR statistic $p < 0.001$.

Note: *** and ** represent significance at 1% and 5%, respectively. Odds ratios are computed as $OR = \exp(\beta)$.

Source: authors' research.

limited liquidity or competing consumption needs may underinvest, consistent with human capital and credit-constraint logic (Becker, 1964). Household size could also increase on-farm labor availability, which might reduce the perceived need for time-saving technologies.

Access to credit was significant at the 5% level and positively associated with farmers' likelihood of using digital technology. The data revealed that rice farmers who could obtain financing were over 10 times more likely to adopt digital technology than those without, as demonstrated by the odds ratio of 10.35. This research correlates with the findings of Mohammed and Temu (2008) and Amin et al. (2020), who discovered that financial accessibility has been proven to boost the adoption of new technologies. It removes a major affordability barrier, since liquidity constraints could hinder adoption. It might also connect farmers to formal networks (cooperatives, markets) that expose them to new technologies and reduce informational frictions.

Awareness of digital technology was strongly associated with adoption ($OR = 8.4, p < 0.01$). Farmers who were aware of digital technologies were 8.4 times more likely to accept and use them than those unaware. This underscores the central role of information and awareness as prerequisites for uptake. According to diffu-

sion of innovation theory, awareness (knowledge) is the first step in the adoption process, as it allows farmers to perceive the relative advantage and compatibility of digital tools, thereby reducing uncertainty and encouraging uptake (Rogers, 2003). Rice farming experience demonstrated a positive significance at 5% and an odds ratio of 1.16, meaning that each additional year of experience increased the odds of adoption by roughly 16%. More experienced farmers may better appreciate the practical benefits of specific digital tools and integrate them into existing routines.

Effect of digital technologies on the productivity of rice farmers

The regression outcome in Table 6 used the output-variable-cost ratio (value of output/total variable cost) as a productivity proxy. The model explained 54.5% of the variance in this productivity proxy ($R^2 = 0.545$), and the F-statistic was significant ($p < 0.01$). Key variables associated with productivity of the rice farmers were the purpose of use of digital technologies, frequency of use, and communication with extension agents via the use of digital technologies (i.e., mobile phones) for receiving and delivering information.

The purpose of using digital technologies was positively associated with the productivity proxy ($p < 0.01$). *Ceteris paribus*, farmers who used digi-

tal technologies for rice production had a 1.927-unit higher productivity proxy than those who did not. The purposeful use of digital tools for rice production allows farmers to convert information into more accurate and effective farm-level decisions. Similarly, frequency of digital technology use was positively associated with productivity ($p < 0.01$). Farmers who used digital technologies more regularly (e.g., daily during rice cultivation) had a 1.258-unit higher productivity proxy than infrequent users. Frequent use of digital tools keeps farmers updated on rapidly changing conditions, enabling them to apply recommendations more quickly and accurately. Consequently, this increased use enhances the intensity and reliability of information flow, which can contribute to higher productivity.

Communication with extension agents via mobile phones was also positively associated with productivity at the 1% level. Farmers who consulted extension agents by phone about rice cultivation recorded a higher productivity proxy score than those who did not. Mobile-phone contact with extension agents may shorten the feedback loop between field observations and expert advice, enabling general recommendations to be adapted into context-specific actions. Dagunga et al. (2018) reported that extension services provide farmers with knowledge of improved farming techniques and strategies to better manage agricultural risks and uncertainties.

Conversely, productivity was not significantly as-

sociated with age, years of schooling, and the number of network usage. These findings indicate that how and how often digital technologies are used, especially for production and extension-related purposes, matter more for productivity outcomes. These results were consistent with Khatun and Haider (2016), who noted potential productivity gains from purposeful manipulation of technology adoption in different phases of agricultural production. Similarly, Ali et al. (2016) found that there was a favorable influence of ICTs on agricultural productivity. This also aligns with evidence that phone use specifically for agricultural activities was associated with higher yields (Quandt et al., 2020).

Constraints to the utilization of digital technologies among rice farmers

Table 7 identifies the challenges rice farmers in the research area face when utilizing digital technologies. Ranked by mean score, the top barriers were little or no internet network access (2.95), inadequate power supply (2.94), poor access to credit (2.76), high mobile phone costs (2.74), poor access to extension agents (2.25), and lack of literacy (2.09). These results indicated that infrastructure (network connectivity, electricity) and affordability (credit, device cost) were the primary constraints to digital adoption among rice farmers in the study area, with institutional factors

Table 6. Effect of digital technologies on rice farmers' productivity

Variable	Coefficient	SE	p
Age [years]	-0.031	0.020	0.131
Level of education [years of schooling]	-0.029	0.039	0.469
Purpose of usage of digital technology	1.927***	0.342	<0.001
Number of networks used	-0.294	0.183	0.109
Frequency of usage of digital technologies	1.258***	0.356	0.001
Communication with extension agents via mobile phones	1.396***	0.454	0.003
Constant	5.083	1.149	<0.001

$R^2 = 0.545$; adjusted $R^2 = 0.526$; $F = 31.76$; $p < 0.001$; $N = 151$.

Notes: The dependent variable is the output-variable-cost ratio (A/TVC), used as a productivity proxy. Robust standard errors (HC1) were reported to correct for heteroskedasticity, as confirmed by the Breusch–Pagan test ($p < 0.05$). This ensures valid statistical inference without affecting coefficient estimates. Multicollinearity was assessed using variance inflation factors (VIF), and all values were below the commonly accepted threshold of 5, indicating no serious multicollinearity concerns. *** and ** represent significance at 1% and 5% levels, respectively.

Source: authors' research.

(limited access to extension agents) and skills/literacy gaps also playing a role.

These findings corroborate earlier studies. Mwakaje (2010) reported that 68% of respondents lacked funds to purchase ICT services or facilities, 8.5% could not cover associated operating costs, and 4% admitted a lack of ICT knowledge. Kituyi-Kwake and Adigun (2008) found that expensive services accounted for 32% of barriers to ICT adoption. Similarly, Jayathilake et al. (2008) studied ICT adoption and its effect on Sri Lankan agriculture and found that high technology costs were the largest barrier, while farmers' limited capacity and lack of training further hindered implementation. Furthermore, Musa et al. (2012) indicated that 50.8% of farmers had little or no access to energy (solar or grid), which made it difficult for them to use ICTs. This discovery was based on the restrictions associated with poor infrastructure support.

STUDY LIMITATIONS

Despite these useful insights, the findings should be interpreted within certain limitations. The study was conducted in a single region (Kwara State), which restricts the geographical generalizability of the results. In addition, the sample was overwhelmingly male, which may reflect either male dominance in rice farming or a response bias, in which men were more

likely than women to participate in the survey rather than the actual gender distribution of rice farmers. This distinction should be considered when interpreting gender-related implications of the results. Future studies should therefore include more diverse samples across regions and genders to improve representativeness. The dependent variable used in the productivity regressions was the output-variable-cost ratio (A/TVC), which serves as a proxy for productivity rather than a formal total factor productivity (TFP) measure. This was because detailed input quantity data required for TFP estimation were not sufficiently available for all sampled farmers. Given these data constraints and the cross-sectional, observational nature of the survey, the estimated relationships are associations and should not be interpreted as causal effects. Future research with richer input data or panel datasets could estimate TFP using production function or index number approaches and strengthen causal inference.

CONCLUSIONS AND RECOMMENDATIONS

This study examined how digital technology affects rice production among farmers in Kwara State, Nigeria. A total of 151 rice farmers were sampled in three stages using a structured questionnaire to obtain primary data. Descriptive statistics, the sigma scoring method, the logit regression model, ordinary least

Table 7. Constraints to utilize digital technologies among rice farmers ($N = 151$)

Constraint	Strongly disagree	Disagree	Agree	Strongly agree	Mean	Rank
Little or no internet network access	0(0.00)	33(21.85)	93(61.59)	25(16.56)	2.95	1 st
Inadequate power supply	1(0.66)	32(21.19)	93(61.59)	25(16.56)	2.94	2 nd
Poor access to credit	2(1.32)	41(27.15)	99(65.56)	9(5.96)	2.76	3 rd
High cost of mobile phones	3(1.99)	50(33.11)	82(54.30)	16(10.60)	2.74	4 th
Poor access to extension agent	1(0.66)	116(76.82)	30(19.87)	4(2.65)	2.25	5 th
Lack of literacy	3(1.99)	133(88.08)	14(9.27)	1(0.66)	2.09	6 th

Note: Values in parentheses are percentages.

Source: authors' research.

squares regression, and a Likert-type scale were used to analyze the data.

Based on the study's findings, approximately 74.17% of the respondents were middle-aged (20–40 years old) with an average age of 35. Most respondents (99.34%) were male, and 59.60% had a tertiary education. Household sizes typically ranged from 6 members to 10 members, with around 82.12% of respondents being married. Additionally, 97% of participants identified farming as their primary occupation. Most farmers were small to medium-sized, owning 5–10 ha of land. The average rice farming experience was 17 years, and 55.63% of respondents belonged to at least one cooperative or farm organization. With a high sigma score of 5.94, the study concluded that mobile phones were the most extensively used digital tools among farmers. Adoption of digital technology was significantly influenced by age ($p < 0.01$), level of digital awareness ($p < 0.01$), household size ($p < 0.05$), access to finance ($p < 0.05$), and rice farming experience ($p < 0.05$). Further analysis indicated that the purpose of digital technology use, frequency of use, and the use of mobile phones for communication with extension agents had a statistically significant positive association with rice output. The main challenges to adopting digital technology among rice farmers included limited network connectivity, inadequate power supply, poor access to funding, high cost of mobile phones, limited access to extension agents, and low literacy levels.

The research indicated that rice farmers' digital technology adoption was largely mobile phones, and it was associated with higher productivity. The usefulness of mobile phone usage has been impeded by inadequate access to network, insufficient power supply, low access to credit, high cost of mobile phones, poor access to extension agents and lack of literacy.

The following suggestions were provided considering the research findings:

1. Since digital technologies (purpose of usage and frequency of usage) were positively associated with productivity, there is a need for targeted awareness and digital literacy training among farmers on the uses and benefits of digital technologies for improved productivity.
2. The Nigerian government and development partners should create an enabling environment

and improve digital rural infrastructure to enhance farmers' adoption of digital technologies.

3. To enable farmers (especially smallholder farmers) to use digital technologies to access modern information sources, the government should create accessible credit facilities.

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WPŁYW TECHNOLOGII CYFROWYCH NA WYDAJNOŚĆ PRODUKCJI RYŻU W STANIE KWARA W NIGERII

STRESZCZENIE

Cel: Produkcja ryżu w Nigerii nie zaspokaja krajowego popytu, co zwiększa zależność od importu. Technologie cyfrowe mogą zwiększać produktywność poprzez usprawnienie przepływu informacji, planowania i podejmowania decyzji, jednak ich wykorzystanie wśród rolników uprawiających ryż jest ograniczone i słabo zbadane. Niniejsze badanie analizuje wpływ technologii cyfrowych na produktywność ryżu w stanie Kwara w Nigerii. **Metody:** Dane pierwotne zebrano od 151 rolników przy użyciu trzystopniowej procedury doboru próby. W analizie zastosowano statystyki opisowe, modele regresji, metodę punktacji sigma oraz skalę Likerta. **Wyniki:** Wyniki wskazują, że telefony komórkowe są najczęściej wykorzystywanym narzędziem cyfrowym; ich użycie, szczególnie do komunikacji z doradcami rolniczymi, było istotnie związane z większą produktywnością ryżu. Do głównych czynników determinujących to wykorzystanie należą wiek, wielkość gospodarstwa domowego, świadomość cyfrowa, doświadczenie rolnicze oraz dostęp do finansowania. Pomimo korzyści wykorzystanie technologii cyfrowych jest ograniczane przez wysokie koszty, słabe pokrycie siecią, niestabilne dostawy energii elektrycznej, ograniczony dostęp do usług doradczych oraz utrudniony dostęp do kredytu. **Wnioski:** Dzięki badaniom udowodniono, że technologie cyfrowe sprzyjają zwiększeniu produktywności ryżu, jednak ich potencjał transformacyjny jest ograniczony przez bariery infrastrukturalne i instytucjonalne. Rekomendacje obejmują wzmocnienie kompetencji cyfrowych, rozwój infrastruktury telekomunikacyjnej na obszarach wiejskich oraz poprawę dostępu do finansowania, co może przyczynić się do szerszego wykorzystania technologii, wzrostu produktywności oraz wsparcia bezpieczeństwa żywnościowego i rozwoju zrównoważonego rolnictwa w Nigerii.

Słowa kluczowe: produktywność, metoda punktacji sigma, model regresji logitowej, klasyczna metoda najmniejszych kwadratów, technologia cyfrowa, rolnicy uprawiający ryż, stan Kwara

FUELING CHANGE IN TANZANIA: UNCOVERING WHAT DRIVES WOMEN'S WILLINGNESS TO PAY FOR COOKING GAS

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ABSTRACT

Aim: This study examines the determinants of women's willingness to pay for cooking gas in Kilimanjaro, Tanzania, using household utility theory and the energy ladder theory. **Methods:** The study adopted a quantitative research approach with a cross-sectional design, and employed the contingent valuation method (CVM) using a payment scale format. The study was conducted with a sample of 150 women, selected through a multi-stage sampling process to ensure representation across the target population. The data source was primary data collected using a structured questionnaire. Descriptive analysis and a probit model were employed to analyze the data. **Results:** The study finds that women's willingness to pay (WTP) for cooking gas is positively and significantly influenced by household size, average monthly household income, awareness of liquefied petroleum gas (LPG) availability, the presence of a gas plant within the community, and proximity to selling points within a distance of 1–3 km. Conversely, affordability challenges and the frequency of cooking gas purchases have a negative, significant effect on WTP, indicating that high costs and frequent refills discourage consistent use and willingness to pay for cooking gas among women. **Conclusion:** Policies should focus on improving LPG infrastructure, raising awareness, expanding income opportunities, and providing targeted subsidies to address affordability and reduce purchase – frequency barriers for women.

Key words: willingness to pay, cooking gas, woman, probit model, Tanzania

JEL codes: D1, Q4, Q42

INTRODUCTION

Globally, the promotion of the use of clean and renewable energy has been prioritized through various interventions that focus on strengthening energy security, expanding access to renewable energy, advancing energy-efficient technologies, and improving overall energy use efficiency (Bersisa et al., 2021; Kitole et al., 2023; Chanda et al., 2025; Kebele et al., 2025).

Moreover, Sustainable Development Goal 7 (SDG 7) underscores this commitment by aiming to ensure universal access to affordable, reliable, sustainable, and modern energy by 2030 (United Nations [UN], 2015; Bai et al., 2023; Kitole et al., 2023; Afriyie et al., 2024; Dunga & Goswami, 2025; Zhao et al., 2025). Access to clean and affordable energy remains limited for many households, with only 17% of African households having access to clean cooking fuels

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(International Energy Agency [IEA], 2022; Kitole et al., 2023; Dumga & Goswami, 2025; Tornel-Vázquez et al., 2025). Globally, about 2.6 billion people rely on traditional biomass, coal, or kerosene, posing serious health and environmental risks that hinder progress toward SDG 7 (Bakhsh et al., 2020; IEA, 2020; Bersisa et al., 2021; Kitole et al., 2023; Bawakyillenuo et al., 2025; Zhao et al., 2025). Households that adopt clean energy show willingness to allocate part of their monthly budget, making WTP a key factor in transitioning from biomass to cleaner fuels (Sievert & Steinbuks, 2020; Dumga & Goswami, 2025).

In Africa, especially where wood and charcoal dominate, understanding WTP is essential for promoting sustainable energy, improving health outcomes, and reducing environmental degradation (Dumga & Goswami, 2025). In Tanzania, particularly the Kilimanjaro region, assessing women's WTP for cooking gas informs policies on clean energy adoption, gender empowerment, and the mitigation of indoor air pollution, deforestation, and greenhouse gas emissions (World Bank [WB], 2022; Ministry of Energy of the United Republic of Tanzania [URT], 2024).

Globally, high upfront costs, limited infrastructure, and low awareness slow both the willingness to pay for and the adoption of cooking gas (IEA, 2021). In Africa, poverty, weak distribution networks, and cheaper alternatives such as charcoal further hinder uptake despite the health and environmental benefits (World Health Organization [WHO], 2022). In Tanzania, including the Kilimanjaro region, low household incomes, limited subsidies, high distribution costs, rural remoteness, and cultural preferences reduce women's willingness to pay for liquefied petroleum gas (LPG) (URT, 2015). Only 7.9% of Tanzanian households are willing to use and pay for cooking gas, highlighting extremely low adoption. Traditional fuels dominate, with over 80% of the population relying on firewood (58.6%), charcoal (27.1%), and kerosene (1.2%), while LPG (9.2%) and electricity (2.5%) remain limited (URT, 2024). This reliance reflects broader adoption challenges, including limited awareness, poor access to efficient cookstoves, affordability constraints, and inadequate knowledge on using and maintaining clean cooking solutions (URT, 2024).

To address the challenges, global efforts emphasize expanding access to clean cooking, offering affordable

financing, and reducing environmental harm from traditional fuels (Clean Cooking Alliance [CCA], 2021). Across Africa, governments are introducing subsidies, improving infrastructure, and raising awareness to encourage the shift from biomass to gas (Aikins & McLachlan, 2020; Gafa & Egbendewe, 2021; Twumasi et al., 2021). In Tanzania, initiatives led by the government and NGOs focus on LPG promotion subsidies, education, and private sector partnerships, especially in regions including Kilimanjaro (URT, 2023), through providing tax relief to stimulate the use of LPG in the country (URT, 2015). Also, in 2023, the Tanzania LPG Association (TZLPGA) was established, bringing together six major companies involved in the household gas cylinder trade, including Cam-Gas, O-Gas, Lake Gas, Taifa Gas, Oryx Gas, Manji Gas, and Puma Energy to promote the use of LPG for cooking (URT, 2023). Additionally, the enactment of the Rural Energy Act of 2005 (URT, 2005), National Energy Policy of 2015 and Rural Energy Fund (URT, 2015), Rural Energy Agency (REA) as well as National Renewable Energy Strategy, 2024–2034 (URT, 2024), and increased budget allocations aim to promote greater use of LPG (URT, 2023). Over the past decade, the supply of LPG for household cooking has grown significantly (URT, 2015). However, the success of any policy intervention largely depends on consumers' preferences and their willingness to pay for clean energy, including cooking gas (Bersisa et al., 2021). Fostering willingness to pay for cooking gas requires an understanding of the drivers and obstacles to it.

The existing studies primarily examine the determinants of adoption of improved cookstoves, willingness to pay for electricity connections, and the use of various fuel types in countries (Numata et al., 2012; Sievert & Steinbuks, 2020; Bersisa et al., 2021; Chindarkar et al., 2021; Onyekuru et al., 2021; Das et al., 2022; Wen et al., 2022; Dumga & Goswami, 2025). In Tanzania, research has largely been confined to studying the drivers of cooking energy choice. Scanty studies (Rosenbaum et al., 2015; Bersisa et al., 2021) in developing countries, including Tanzania, have been conducted on drivers of willingness to pay for cooking gas, such as LPG for cooking. The recent existing studies (Osiolo, 2017; Pyzalska-Kowalska, 2019; Ayodele et al., 2021; Das et al., 2022; Ma

et al., 2022; Nketiah et al., 2022; Janghorban et al., 2024; Chishimba & Muchapondwa, 2025; Dumga & Goswami, 2025; Kebele et al., 2025; Tornel-Vázquez et al., 2025) on determinants of willingness to pay for cooking energy focused much on cooking electricity, household electricity, renewable electricity, green electricity, and improved cookstoves, including biomass and gas stoves as well as ICSs, traditional fuels such as firewood and charcoal, and solar cookers. For example, Kebele et al. (2025) studied solar cookers in peri-urban Tigray, Ethiopia. Bersisa et al. (2021) investigated improved cookstoves, including biomass and gas stoves, in rural Ethiopia, and Dumga and Goswami (2025) analyzed electricity use for cooking in rural Southern Ethiopia. Osiolo (2017) assessed firewood, charcoal, and electricity for households and enterprises in Kenya, whereas Rosenbaum et al. (2015) evaluated improved cookstoves in Bangladesh. Janghorban et al. (2024) examined household and SME electricity connections in Nigeria, and Das et al. (2022) examined firewood use in the peri-urban Kathmandu Valley, Nepal. Pyzalska-Kowalska (2019) studied residential consumers' willingness to pay for green electricity in Poland, Ayodele et al. (2021) explored renewable electricity in Nigeria, and Nketiah et al. (2022) analyzed renewable green electricity in Ghana.

Limited studies (Chindarkar et al., 2021; Das et al., 2022) focused on cooking gas such as LPG. For instance, Chindarkar et al. (2021) focused on households' willingness to pay for LPG for cooking in rural India, while Das et al. (2022) study focused on LPG in the peri-urban Kathmandu Valley, Nepal. This issue remains underexplored in the context of cooking gas in rural areas, where most households in developing countries, including Tanzania, reside and have markedly different livelihood conditions. Studies show that willingness to pay (WTP) for clean energy is primarily influenced by socio-economic factors such as income, education, household size, and gender (Sievert & Steinbuks, 2020; Ayodele et al., 2021; Bersisa et al., 2021; Chindarkar et al., 2021; Das et al., 2022; Tornel-Vázquez et al., 2025). Behavioral factors, including awareness of health and environmental benefits, community influence, and government involvement, also increase WTP (Das et al., 2022; Nketiah et al.,

2022). However, structural barriers such as price sensitivity, income instability, and limited infrastructure constrain adoption (Pyzalska-Kowalska, 2019; Bersisa et al., 2021; Dumga & Goswami, 2025). Nevertheless, these studies often overlooked fully examining factors such as the frequency of purchasing cooking gas, time savings relative to traditional fuels, and training in the use of clean cooking energy that influence women's willingness to pay for cooking gas. Furthermore, existing studies have largely overlooked women, even though in rural households they bear primary responsibility for collecting and transporting cooking energy sources, devoting a significant portion of their time and effort to these tasks (Dumga & Goswami, 2025). This study addresses these gaps by including the influence of the above-overlooked factors to offer an understanding of the drivers of women's willingness to pay for cooking gas in Kilimanjaro, Tanzania.

LITERATURE REVIEW

The energy ladder theory

The energy ladder theory, developed by Leach (1992), proposes that as household income increases, fuel use transitions from traditional fuels such as firewood and dung to transitional fuels like charcoal and kerosene, and ultimately to modern fuels including LPG and electricity (Bensch et al., 2021; Pangaribowo & Iskandar, 2022). The theory assumes that fuel choice follows a linear progression with rising income, that modern fuels are universally preferred when affordable, and that fuel decisions are largely driven by income, affordability, and accessibility (Pangaribowo & Iskandar, 2022). The fuel choice implies the willingness to pay for cooking gas. In the context of this study, women, based on income increase, can be willing to pay for cooking gas, such as LPG, as a transition from traditional fuels.

The energy ladder theory offers several strengths. It provides a clear conceptual framework for understanding socio-economic transitions in household energy use, explains patterns of fuel switching, and supports planning for energy infrastructure and clean energy policies (Kitole et al., 2023). The theory is particularly relevant to this study as it aligns

with the analysis of key determinants of willingness to pay for cooking gas, including income, affordability, and price. It also offers a theoretical basis for understanding the economic transition from traditional fuels to cooking gas such as LPG.

Despite its usefulness, the theory has notable limitations. It oversimplifies household energy behavior by assuming a linear transition and failing to account for fuel stacking, the simultaneous use of multiple fuels. It also neglects cultural, behavioral, and contextual factors that shape energy choices and willingness to pay. Furthermore, it assumes rational decision-making while overlooking concerns such as safety perceptions, time savings, and preferences for specific energy sources. As such, non-income determinants of household energy decisions, which are omitted in this framework, are more adequately captured within household utility theory.

Household utility theory

Household decisions regarding the willingness to pay for cooking energy are grounded in rational choice. According to the theory, households consider both their preferences for cooking energy sources and budget constraints when selecting the energy source that maximizes their perceived utility (Greve & Lay, 2023; Kitole et al., 2023). Willingness to pay for cooking energy, particularly modern fuels such as LPG, is influenced by a range of socio-economic characteristics that vary across households. In this study, willingness to pay for cooking gas is considered the dependent variable. For a household that expresses a willingness to pay, the corresponding utility function can be represented as follows:

$$U_j = \beta'x_j + \epsilon_j, j = 1, 2 \quad (1)$$

when the household choice j is made, the underlined assumption (U_j) achieves the maximum value among the available set of utilities. That is, j is chosen when $U(\text{alternative } j) > U(\text{alternative } k)$, $k \neq j$ is a vector of explanatory variables that affect the willingness to pay (WTP) for cooking gas, D^* is a latent variable that indicates the willingness to pay (WTP) for cooking gas, β' is a vector of unknown parameters, ϵ_j and is a disturbance term.

Empirical literature on the drivers of willingness to pay for cooking energy

The literature on households' willingness to pay (WTP) for clean cooking energy and renewable electricity highlights consistent patterns and challenges across diverse geographic and socio-economic contexts. Across India, Ethiopia, Nepal, Nigeria, Ghana, Poland, and Bangladesh, socio-economic factors such as income, education, household size, and gender emerge as strong predictors of WTP (Ayodele et al., 2021; Bersisa et al., 2021; Chindarkar et al., 2021; Das et al., 2022). Wealthier and more educated households consistently exhibit higher WTP, reflecting both greater financial capacity and greater awareness of the health, time-saving, and environmental benefits of adopting clean energy. Similarly, household composition, including the number of productive-age members, affects WTP by influencing labor availability and energy needs (Kebele et al., 2025). Behavioral and awareness factors also play a critical role. Studies show that recognition of health advantages, environmental impacts, and community adoption increases WTP (Chindarkar et al., 2021; Das et al., 2022; Nketiah et al., 2022). Tornel-Vázquez et al. (2025) examined the adoption of nature-based solutions for energy transition among rural households in Northern Nigeria using a two-stage Heckman selection model. Their analysis of willingness to pay (WTP) indicated that several factors were positively associated with higher WTP, including household size, time spent on food preparation, biomass use, participation in informative workshops, and household income. The Ghana study demonstrates that government involvement and awareness campaigns indirectly enhance WTP by shaping attitudes and subjective norms, while perceived behavioral control alone does not significantly influence payment behavior. Social dynamics can both encourage and constrain adoption; for instance, participation in community organizations was associated with lower WTP in Tigray, possibly due to social norms or shared resource strategies (Kebele et al., 2025). Fuel stacking in Nepal shows households often use traditional fuels alongside LPG, influenced by availability, cost, and convenience (Das et al., 2022). Economic and structural barriers, including price sen-

sitivity and limited ability to pay full market prices, constrain WTP for clean energy (Pyzalska-Kowalska, 2019; Chindarkar et al., 2021; Bersisa et al., 2021). Income instability, cash flow issues, and infrastructure challenges such as distance to distribution points further limit adoption (Bersisa et al., 2021; Das et al., 2022; Dumga & Goswami, 2025). Even in higher-income contexts such as Poland and Nigeria, WTP remains moderate, underscoring the need for subsidies, flexible financing, and targeted interventions to support clean energy adoption (Pyzalska-Kowalska, 2019; Ayodele et al., 2021).

Across studies, various models estimate willingness to pay (WTP) for different energy types, including Probit, Ordered Probit, and double-bounded contingent valuation approaches (Osiolo, 2017; Bersisa et al., 2021; Kebele et al., 2025). Conditional logit and structural equation models capture household and SME preferences, as well as the role of attitudes and social norms in shaping WTP (Nketiah et al., 2022; Janghorban et al., 2024). CVM has been widely applied to assess WTP for renewable and clean energy across countries like Poland, Nigeria, and Nepal (Pyzalska-Kowalska, 2019; Ayodele et al., 2021; Das et al., 2022). Experimental trials and behavioral assessments further reveal adoption patterns and preferences, highlighting methodological diversity in studying energy WTP (Rosenbaum et al., 2015).

Methodologically, studies use contingent valuation, double-bounded CV, discrete choice experiments, and choice modeling to estimate stated preferences and marginal WTP for clean energy (Bersisa et al., 2021; Chindarkar et al., 2021; Janghorban et al., 2024). Structural equation modeling highlights the influence of attitudes and social norms, while discrete choice experiments capture heterogeneity in household and SME preferences (Nketiah et al., 2022; Janghorban et al., 2024). However, comparisons across studies are limited by differences in elicitation methods, samples, and contexts, reducing generalizability. Key gaps include limited evidence from rural and low-income settings, a lack of longitudinal analysis, and a minimal focus on multi-fuel (fuel stacking) decision-making. Overall, WTP is shaped by socio-economic status, awareness, and communi-

ty effects, but high costs, weak infrastructure, and income variability constrain full and sustained clean energy adoption.

DATA AND METHODS

This study employed cross-sectional data collected in the Kilimanjaro region of Tanzania, where many households still rely on traditional cooking fuels such as charcoal and firewood, making it a relevant setting for examining willingness to pay for cleaner energy sources such as cooking gas (URT, 2015; Kitole et al., 2023). The research was conducted specifically in rural areas of Hai District, one of the seven districts in the Kilimanjaro Region (NBS & REA, 2020). A multi-stage sampling strategy was applied. First, Hai District was purposively selected because of its greater reliance on traditional cooking methods than the surrounding districts. Second, two wards, including Machame Magharibi and Machame Uroki, were purposively chosen within the district. Finally, simple random sampling was used to select women-headed households for participation. The sample size was determined using the formula provided by Yamane's formula (1973) as follows:

$$n = \frac{z^2 pq N}{e^2(N-1) + z^2 pq} \quad (2)$$

$$n = \frac{1.96^2 \cdot 0.1117 \cdot 0.888 \cdot 14,254}{0.015(14,254 - 1) + 1.96^2 \cdot 0.1117 \cdot 0.888}, \quad n = \frac{5,212.999}{34.087} = 150$$

where n is a required sample size, N is a total population size, z is a standard normal deviate corresponding to the desired confidence level (e.g., z equals 1.96 for 95% confidence), p is an estimated proportion of the population possessing the characteristic of interest, $q = 1 - p$ (the proportion of the population not possessing the characteristic), and e is an acceptable margin of error (level of precision).

The study surveyed 150 women in 2025 using a structured questionnaire and applied the contingent valuation method (CVM) to estimate women's willingness to pay for cooking gas. CVM requires careful design of WTP questions, as the elicitation format significantly influences respondents' answers (Hanemann, 1984; Pyzalska-Kowalska, 2019). The literature

identifies four main WTP elicitation formats: bidding/bargaining, payment scale, open-ended, and dichotomous choice (Oerlemans et al., 2016). Each format varies in structure and response burden, affecting the reliability and validity of WTP estimates (Yoo & Kwak, 2009; Zoric & Hrovatin, 2012; Ntanos et al., 2018; Dumga & Goswami, 2025). The study applied the contingent valuation method using a payment scale format to estimate women's willingness to pay for cooking gas, selected for its simplicity and practicality (Ntanos et al., 2018). Monetary ranges were defined from pre-tests and market prices: below TZS 20,000; TZS 20,000–50,000; TZS 50,001–100,000; and above TZS 100,000, with a zero WTP option included. Women selected the maximum monthly amount they were willing to pay, and households perceiving higher benefits from LPG showed a higher likelihood of willingness to pay.

$$\text{mean WTP} = \frac{\beta(\text{number of respondents} \times \text{midpoint of category})}{\text{total respondents}} \quad (3)$$

For the top category (“Above TZS 100,000”), the study involved assigning a reasonable assumed value (TZS 120,000) based on context (Ntanos et al., 2018). The binary dependent variable indicates whether a household is classified as a high-cooking-gas expenditure user. The threshold of TZS 100,000 was selected because it represents the upper expenditure class in the survey instrument. For respondents reporting expenditure in the category (“Above TZS 100,000”), an assumed representative value of TZS 120,000 was assigned to approximate actual expenditure, following the common practice for handling open-ended expenditure classes, as recommended by Ntanos et al. (2018). The dependent variable for each household is dichotomous: a response of “yes” (1) if the women's WTP exceeds the market price of cooking gas (small or big size), and “no” (0) if it does not. In other words, a respondent answers “yes” (1) when their WTP is greater than the market price of cooking gas (refilling), and “no” (0) otherwise. The WTP model can be formally expressed as shown in Equation (1),

$$WTP_i(x_i, \epsilon_i) = y_i(x_i, \epsilon_i) = x_i\beta + \epsilon_i \quad (4)$$

where x_i is a vector of explanatory variables, β is a vector of parameters, and ϵ_i is an error term. The probability of observing a “yes” response given the values of is given by:

$$P(x_i = 1|x_i) = P(y_i > t_i) = P(x_i\beta + \epsilon_i > t_i) = P(\epsilon_i > t_i - x_i\beta) \quad (5)$$

A probit model was used to estimate the binary decision of whether a woman is willing to pay more than TZS 100,000 for cooking gas (1 = yes, 0 = no). The model, estimated using maximum likelihood, is appropriate for probability analysis with a normally distributed error term (Berkson, 1944; Becker & Waldman, 1987). Its suitability for socio-economic binary choice analysis, as shown in studies such as Kebele et al. (2025), justifies its application in this study.

The general form of the probit model is expressed as follows:

$$D_i^* = \beta'x_i + u_i \quad (6)$$

$$D_i = \begin{cases} 1 & \text{if } D_i^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

where D_i is an observed dummy variable that indicates whether a woman is willing to pay (WTP) for cooking gas, and subscript i indicates a woman. x_i is a vector of explanatory variables that affect the willingness to pay (WTP) for cooking gas, D^* is a latent variable that indicates the willingness to pay (WTP) for cooking gas, β' is a vector of unknown parameters, and $u \sim N(0, 1)$ is a disturbance term. The marginal effects derived from the model show how a unit change in each independent variable affects the probability of willingness to pay, holding other factors constant. It can be specified as:

$$\frac{\delta(Y = 1|X)}{\delta X_i} = \phi(X\beta)\beta_i \quad (7)$$

where $\phi(\cdot)$ is a probability density function (PDF) of the standard normal distribution, β_i is a coefficient of the explanatory variable. The marginal effect (ME) shows the change in the probability that $Y = 1$ for a one-unit increase in X_i , holding other variables constant. ME is interpreted as average marginal effects (AME). The explanatory variables included age, marital status, education, household size, average household income per month, frequency of purchasing cooking gas, health concerns on use of traditional energy, time

saving relative to traditional fuels, environmental impact on using firewood/charcoal, safety in using cooking gas, awareness on availability of LPG, training on use of clean cooking energy, the presence of gas plant within the community, distance from home to the selling point and affordability. The selected explanatory variables (characteristics and factors) were specifically chosen to examine farmers' responses based on insights from the theoretical framework (household utility theory and energy ladder theory), a review of similar literature, and the local situation.

RESULTS AND DISCUSSION

Descriptive results

Tables 1 and 2 provide the descriptive characteristics of respondents and their willingness to pay (WTP) for cooking gas. Most respondents are over 40 years old, indicating that older household heads mainly influence LPG decisions and may prioritize health and safety benefits. Limited participation of younger households could affect future adoption trends, suggesting a need for age-inclusive LPG promotion strategies. Most respondents are married (67.33%), meaning LPG decisions are largely made at the family level, while widowed households (27.33%) may face financial constraints. Targeting household decision-makers is key to increasing LPG adoption. Over 85% have secondary or higher education, which supports awareness of LPG safety, health, and environmental benefits. However, lower-educated households need training and awareness to reduce fear and misinformation. Medium-sized households (4–7 members) dominate, while larger households face higher LPG costs that may limit adoption. Household size directly affects fuel demand and affordability.

About 74.67% of households are willing to pay for cooking gas, with the largest share (32.67%) able to pay above TZS 100,000, indicating strong demand among higher-income households. However, 25.33% are unwilling to pay, and many can only afford lower amounts, showing that affordability remains a key barrier to wider LPG adoption. The mean willingness to pay for cooking gas is about TZS 58,867 per month,

indicating moderate affordability and readiness to adopt cleaner energy. However, many households may still struggle to use LPG consistently if prices rise above this level. Cooking gas is the most used fuel (39.33%), followed by electricity (27.33%), charcoal (22.67%), and firewood (10.67%). This shows progress toward cleaner energy, though reliance on traditional biomass fuels remains significant. Nearly three-quarters earn

Table 1. Demographic characteristics

Category	Frequency	Percentage [%]
Education		
No formal education	9	6.00
Primary education	13	8.67
Secondary education	50	33.33
College/University	78	52.00
Total	150	100.00
Household size		
1–3	55	36.67
4–6	77	51.33
7–8	0	0.00
Above 8	18	12.00
Total	150	100.00
Age [years]		
Less than 18	1	0.67
18–30	14	9.33
31–40	34	22.67
41–50	49	32.67
Above 50	52	34.60
Total	150	100.00
Marital status		
Single	7	4.67
Married	101	67.33
Divorced	1	0.67
Widow	41	27.33
Total	150	100.00

Source: author's research.

Table 2. Descriptive results

Category	Frequency	Percentage [%]
Willingness to pay (WTP) for cooking gas		
Yes	112	74.67
No	38	25.33
Total	150	100.00
Amount relating to WTP for cooking gas [TZS]		
0	38	25.33
Below 20,000	7	4.67
20,000–50,000	33	22.00
50,001–100,000	23	15.33
Above 100,000	49	32.67
Total	150	100.00
Type of cooking fuel currently used by women		
Firewood	16	10.67
Charcoal	34	22.67
Cooking gas	59	39.33
Electricity	41	27.33
Total	150	100.00
Average household income per month [TZS]		
Below 100,000	10	6.67
100,000–500,000	32	21.33
500,001–1,000,000	72	48.00
Above 1,000,000	36	24.00
Total	150	100.00
Frequency of purchasing cooking gas		
Weekly	3	2.00
Bi-weekly	27	18.00
Monthly (once every month)	59	39.33
Occasionally (no fixed schedule/sometimes)	61	40.67
Total	150	100.00
Health concerns on the use of traditional energy		
Strongly disagree	0	0.00
Disagree	1	0.67
Neutral	19	12.67
Agree	50	33.33
Strongly agree	80	53.33
Total	150	100.00
Time-saving relative to traditional fuels		
Strongly disagree	0	0.00
Disagree	3	2.00
Neutral	24	16.00

Category	Frequency	Percentage [%]
Agree	45	30.00
Strongly agree	78	52.00
Total	150	100.00
Perception on negative environmental impact of using firewood/charcoal		
Strongly disagree	0	0.00
Disagree	2	1.33
Neutral	18	12.67
Agree	48	32.00
Strongly agree	81	54.00
Total	150	100.00
Safety in using cooking gas		
Strongly disagree	1	0.67
Disagree	6	4.00
Neutral	20	13.33
Agree	49	32.67
Strongly agree	74	49.33
Total	150	100.00
Awareness on availability of LPG		
Yes	122	81.3
No	28	18.7
Total	150	100.00
Training on use of clean cooking energy		
Yes	51	34.00
No	99	66.00
Total	150	100.00
The presence of gas plant within the community		
Yes	58	38.67
No	54	36.00
Not sure	38	25.33
Total	150	100.00
Distance from home to the selling point		
Less than 1 km	34	22.67
1–3 km	64	42.67
Above 3 km	52	34.67
Total	150	100.00
Affordability (ability to pay the price of LPG)		
Yes	69	46.00
No	66	44.00
Not sure	15	10.00
Total	150	100.00

Source: author's research.

above TZS 500,000, making LPG more affordable for higher-income groups, while low-income households face cost barriers. Income strongly determines consistent LPG use and adoption.

Most households purchase LPG occasionally or monthly, indicating partial adoption and continued reliance on biomass. Cost and supply constraints limit regular LPG consumption. A strong majority recognize the health risks of traditional fuels, making health benefits a major driver of LPG adoption. Public health messaging can further strengthen this motivation. Most respondents agree LPG saves time compared with biomass fuels, especially benefiting women and working households. Convenience is a strong incentive for adoption. High awareness that biomass fuels harm the environment supports positive attitudes toward LPG. Environmental messaging can reinforce clean cooking transitions. Most households perceive LPG as safe, reducing a key barrier to adoption. Targeted training can address remaining safety concerns. Less than half of respondents are aware of LPG availability, limiting uptake despite willingness to pay. Improving market visibility and distribution information is essential.

Only 34% of households have received training, while most lack guidance on safe LPG use. Expanding training programs can reduce safety concerns and support sustained adoption. Less than 40% report having a gas plant nearby, with many uncertainties or lacking access. Weak or unclear infrastructure limits the reliable use of LPG and requires investment and better information. Over one-third of households live more than 3 km from LPG outlets, increasing refill costs and inconvenience. Closer distribution points would encourage more frequent and consistent use. Opinions are evenly split on affordability, showing cost remains a major barrier for many households. Subsidies and flexible payment options are critical for wider LPG adoption.

Results on the drivers of willingness to pay for cooking gas

Table 3 presents the findings on the socio-economic determinants of women's willingness to pay for cooking gas. The study identified several key factors, including affordability, household size, average household income per month, awareness of the availability of LPG,

infrastructure availability (gas plants), distance from home to the selling point between 1 km and 3 km, and frequency of purchasing cooking gas (once every month). The willingness to pay for cooking gas among women is found to be positively and significantly influenced by household size, average household income per month, awareness of the availability of LPG, infrastructure availability (gas plants), and distance from home to the selling point between 1 km and 3 km. Negative and significant influences come from factors such as affordability and the frequency of purchasing cooking gas.

Household size is positively and significantly associated with women's willingness to pay (WTP) for cooking gas at the 10% level. This implies that women from larger households (with more than eight members) are 22.8 percentage points (pp) more likely to be willing to pay for cooking gas compared with those from smaller households, holding other factors constant. Similarly, household income per month shows a positive and statistically significant relationship with WTP at the 5% level, indicating that women from households earning more than one million Tanzanian shillings monthly are 23.5 pp more likely to pay for cooking gas, reflecting the role of income capacity in adopting cleaner energy sources. Awareness of LPG availability is also positively and significantly related to WTP at the 10% level, suggesting that women who know where LPG can be accessed are 17.4 pp more likely to pay for it than those who lack such awareness. Moreover, the presence of gas plants within the community is highly significant (at the 1% level), increasing the probability of women's WTP by 22.2 pp, which underscores the importance of infrastructure in facilitating energy access. Distance to the selling point between 1 km and 3 km is positively significant at the 5% level, showing that women within this range are 24.2 pp more likely to pay for LPG than otherwise – possibly due to improved accessibility without excessive travel burden. Conversely, affordability exhibits a negative and significant effect at the 5% level, meaning that women who perceive LPG as affordable are paradoxically 11.3 pp less likely to be willing to pay than women who perceive LPG is not affordable, possibly due to expectations of subsidized prices or prior access through informal means. Finally,

Table 3. Results of the probit model of socio-economic factors influencing willingness to pay for cooking gas among women

Variable	Coefficient	SE	$P > z $	ME
Age above 50 years	0.322	0.261	0.218	0.109
Education level (university/college)	0.321	0.251	0.202	-0.106
Household size	0.622	0.375	0.098	0.228
Awareness of the availability of LPG (yes)	0.602	0.347	0.083	0.174
Household average income per month	0.657	0.271	0.015	0.235
Frequency of purchasing cooking gas (yes)	-0.448	0.264	0.090	-0.143
Time saving relative to traditional fuels (yes)	-0.283	0.341	0.407	-0.098
Perception of the negative environmental impact of using firewood/charcoal (yes)	-0.029	0.387	0.941	-0.010
Health concerns on use of traditional energy (yes)	0.574	0.408	0.159	0.163
The presence of gas plants within the community (yes)	0.651	0.253	0.010	0.222
Received training on the use of clean coking energy (yes)	0.145	0.264	0.583	0.049
Affordability of cooking gas (yes)	-0.590	0.256	0.021	-0.191
Safety in using cooking gas	0.212	0.351	0.546	0.067
Distance from home to the selling point (less than 1 km)	0.398	0.326	0.222	-0.139
Distance from home to the selling point of 2–3 km	0.719	0.315	0.023	0.242
Number of observations = 150	Wald chi ² (16) = 42.09	prob>chi ² = 0.0004	pseudo R ² = 0.2345	y = Pr(WTP) 0.271

Notes: $p < 0.10$ is significant at 10% level; $p < 0.05$ is significant at 5% level, and $p < 0.01$ is significant at 1% level. ME is marginal effect interpreted as average marginal effects (AME).

Source: author's research.

the frequency of purchasing cooking gas is negatively and significantly associated with WTP at the 10% level, indicating that women who buy gas monthly are 14.3 pp less likely to pay for it than women who do not buy gas monthly, likely due to the financial strain of frequent expenditures or limited liquidity.

DISCUSSION

The positive and significant relationship between household size and willingness to pay (WTP) for cooking gas suggests that larger families tend to have

higher energy needs and therefore place greater value on adopting LPG for cooking. Bigger households are also more likely to recognize the time and health benefits of clean energy, which leads to higher WTP than in smaller households. The finding is in line with household utility theory and studies of Bersisa et al. (2021), Onyekuru et al. (2021), Kebele et al. (2025), and Tornel-Vázquez et al. (2025). The weakness here is that the relationship may also reflect economies of scale rather than genuine preference, meaning smaller households might still adopt if other barriers, such as price, were addressed.

Higher household income increases the capacity and likelihood of paying for LPG. This aligns with the energy ladder hypothesis, which posits that as income rises, households shift from traditional fuels (such as firewood and charcoal) to cleaner alternatives, such as LPG. Thus, income directly influences affordability and preference for modern energy sources (Kulindwa et al., 2018). The findings are in line with energy ladder theory and household utility theory. Also, the findings concur with the studies of Ayodele et al. (2021), Bersisa et al. (2021), Chindarkar et al. (2021), Tornel-Vázquez et al. (2025). Household income may not capture households that prioritize traditional fuels due to cultural preferences or fuel stacking behavior, limiting the generalizability of the findings.

Awareness plays a critical role in shaping perceptions and trust in LPG as a safe, accessible, and efficient cooking fuel. Households that are well-informed about LPG availability and benefits are more willing to pay, indicating that information campaigns and public sensitization can effectively boost demand. The findings are consistent with theoretical expectations and with the studies of Chindarkar et al. (2021) and Nketiah et al. (2022). Information alone may not translate into actual adoption if financial or infrastructure constraints persist, highlighting a gap between knowledge and behavior.

The presence of gas plants within the community positively influences WTP by reducing supply barriers and ensuring reliable access to refilling services. Adequate infrastructure not only enhances convenience but also builds consumer confidence in sustained availability, encouraging adoption and higher willingness to pay. The finding is consistent with theoretical expectations and previous studies (Das et al., 2022; Dumga & Goswami, 2025). This finding may overestimate effects in regions where supply reliability is inconsistent or where transport costs still pose barriers, limiting applicability to all areas.

A moderate distance to LPG selling points (1–3 km) positively influences WTP, as it represents convenient access without excessive transportation costs or effort. However, distances beyond this range could discourage adoption due to the time and cost burdens of fuel

procurement. The finding is consistent with theoretical expectations and with previous studies of Das et al. (2022) and Dumga and Goswami (2025). However, this measure ignores other contextual factors such as road quality, transportation availability, or safety concerns, which may reduce accessibility in practice.

Affordability has a negative, significant effect on WTP, suggesting that higher LPG prices or limited financial capacity reduce women's willingness to adopt or consistently use cooking gas. This underscores the importance of targeted subsidies, flexible payment schemes, and financing options to lower cost barriers for low-income households. The finding is consistent with theoretical expectations. The measure may not account for households' access to credit, subsidies, or informal sharing arrangements, which can mitigate cost constraints and influence actual behavior.

The negative, statistically significant relationship between the frequency of purchasing cooking gas and willingness to pay (WTP) suggests that women who buy gas more frequently, such as once per month, are less willing to pay higher prices for it. This may be due to the recurring financial burden of frequent refills, which increases sensitivity to price changes and reduces disposable income available for energy expenditure. It may also reflect liquidity constraints or income instability, in which regular payments are perceived as less manageable than infrequent bulk purchases. The finding highlights the importance of promoting affordable refill options, flexible payment systems, or smaller cylinder sizes to reduce the financial strain associated with frequent purchases. The finding is based on theoretical expectations. The negative effect of frequent purchases on WTP highlights financial strain, but it may not consider differences in household storage capacity or consumption patterns, which could moderate the relationship.

Time savings relative to traditional fuels were not significant because many women may not perceive LPG as substantially reducing cooking time compared with charcoal or kerosene, especially when other household chores consume most of their daily time (Chindarkar et al., 2021; Das et al., 2022). Training

on the use of clean cooking energy was not significant because awareness and basic operational knowledge of LPG are already widespread, making additional training less influential in shaping willingness to pay (Bersisa et al., 2021; Nketiah et al., 2022).

CONCLUSIONS AND POLICY IMPLICATIONS

The study concludes that women's willingness to pay for cooking gas increases with household size, income, awareness, and accessibility to LPG infrastructure. Proximity to selling points within 1–3 km also enhances WTP. However, affordability issues and frequent gas purchases reduce it. These findings highlight the need for improved access, affordability measures, and awareness to promote wider LPG adoption. The study findings suggest several key policy implications. First, because larger households show a higher willingness to pay (WTP), policymakers could prioritize awareness-raising and promotional programs targeting smaller households to encourage broader LPG adoption. Second, the positive influence of household income highlights the need for income-enhancing initiatives, such as women's economic empowerment programs, to improve the affordability of clean cooking energy. Third, awareness of LPG availability significantly increases WTP, indicating that public campaigns and community outreach on LPG's benefits and safety are essential. Fourth, improved infrastructure – such as expanding gas plants and distribution networks – can enhance accessibility and reliability, further encouraging adoption. Fifth, shorter distances to selling points increase WTP; thus, policies should promote decentralized LPG retail outlets within 1–3 km of residential areas. Conversely, the affordability challenge underscores the importance of targeted subsidies or installment payment schemes to reduce upfront costs. Lastly, frequent purchasing discourages WTP, implying that policies encouraging larger, cost-effective cylinder refills or bulk-purchase options could enhance consistent LPG use.

LIMITATIONS OF THE STUDY AND AREA FOR FURTHER RESEARCH

Despite its contributions, this study faced several limitations. First, the sample was restricted to selected districts in Kilimanjaro, limiting the generalizability of the findings to other regions or the national level. Second, reliance on self-reported data introduces the possibility of response bias, as participants may over- or under-report their willingness to pay. Future studies should expand to other regions of Tanzania to enable comparative analysis and a broader understanding of determinants across different contexts. In-depth qualitative research is recommended to explore how cultural beliefs, norms, and household power dynamics shape willingness to pay for cooking gas. Additionally, longitudinal studies could track changes over time to assess how shifts in income levels, policy frameworks, and infrastructure development influence households' willingness to pay for cooking gas.

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NAPĘDZANIE ZMIAN W TANZANII: IDENTYFIKACJA CZYNNIKÓW DETERMINUJĄCYCH SKŁONNOŚĆ KOBIEC DO ZAPŁATY ZA GAZ DO GOTOWANIA

STRESZCZENIE

Cel: Celem badania jest identyfikacja determinantów skłonności do zapłaty za gaz do gotowania wśród kobiet zamieszkujących region Kilimandżaro w Tanzanii z zastosowaniem teorii użyteczności gospodarstwa domowego oraz koncepcji drabiny energetycznej. **Metody:** W badaniu zastosowano podejście ilościowe z użyciem przekrojowego schematu badawczego oraz metody wyceny warunkowej (CVM) w formacie skali płatności. Próba badawcza obejmowała 150 kobiet, wytypowanych w wieloetapowym procesie doboru próby w celu zapewnienia reprezentatywności badanej populacji. Wykorzystano dane pierwotne zebrane za pomocą ustrukturyzowanego kwestionariusza ankietowego. Do analizy danych zastosowano statystykę opisową oraz model probitowy. **Wyniki:** Wyniki wskazują, że skłonność do zapłaty (WTP) za gaz do gotowania wśród kobiet jest dodatnio i statystycznie istotnie determinowana przez wielkość gospodarstwa domowego, przeciętny dochód miesięczny gospodarstwa domowego, poziom świadomości dostępności skroplonego gazu ropopochodnego (LPG), obecność infrastruktury gazowej w społeczności lokalnej oraz bliskość punktów sprzedaży (w odległości 1–3 km). Jednocześnie czynniki takie jak ograniczenia dochodowe (przystępność cenowa) oraz częstotliwość zakupu gazu wywierają istotny, negatywny wpływ na WTP, co sugeruje, iż wysokie koszty oraz konieczność częstego uzupełniania zapasów ograniczają skłonność do regularnego korzystania z gazu do gotowania. **Wnioski:** Implikacje dla polityki publicznej wskazują na potrzebę rozwoju infrastruktury LPG, zwiększania poziomu świadomości, wzmacniania możliwości dochodowych gospodarstw domowych oraz wdrażania ukierunkowanych subsydiów w celu ograniczenia barier związanych z przystępnością cenową i częstotliwością zakupu.

Słowa kluczowe: skłonność do zapłaty (WTP), gaz do gotowania, kobieta, model probitowy, Tanzania

SPECIAL ECONOMIC ZONES AS AN INSTRUMENT SUPPORTING THE DEVELOPMENT OF PERIPHERAL REGIONS IN POLAND – THE EXAMPLE OF THE PODLASKIE VOIVODESHIP

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ABSTRACT

Aim: The existence of disparities in the socio-economic development of regions in Poland is a significant issue in the modern economy. In 1994, special economic zones were established. These are designated areas of the country where economic activity can be conducted under preferential terms. The paper highlights the significance of the Suwałki Special Economic Zone (SSEZ) in the context of the development of the Podlaskie Voivodeship, a peripheral region. **Methods:** The functioning of the SSEZ was presented in detail, focusing on the effects of the SSEZ's activities, including the number of permits issued, the size of investments, and the level of employment. Public statistics and data obtained from the SSEZ for the years 2012–2023, as well as the results of a survey (CAWI) conducted in 2024 among employees of one company operating in the SSEZ, and an interview (CAPI) with a representative of the local authorities, were used. **Results:** The research results indicate that the SSEZ had a significant positive impact on the economic development of the Podlaskie Voivodeship, including attracting numerous investments that contributed to increased employment and improved technical infrastructure. The benefits of the SSEZ's activities are evident at the local level. **Conclusions:** Investments in special economic zones have a multiplier effect, generating increased local demand for other services. Monitoring the effects of economically privileged areas may help develop effective instruments to stimulate the socio-economic development of peripheral regions in the future.

Key words: interventionism, Suwałki Special Economic Zone, regional development, peripheral region, Podlaskie Voivodeship

JEL codes: H25, H30, J21, R10

INTRODUCTION

A characteristic feature of regional development in Poland is its high degree of diversity, with significant developmental disparities evident on multiple levels.

The reasons for these differences vary, but they are mainly rooted in historical circumstances (Wojewódzka-Wiewiórska, 2012). At the same time, it highlights existing spatial disparities, with a particular emphasis on the less developed eastern part of Poland. The paper

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concerns the development of the Podlaskie Voivodeship, which, due to its characteristics, is considered a peripheral region (Kozak, 2014). The Suwałki Special Economic Zone (SSEZ) has been operating in the Podlaskie Voivodeship since 1996 and is an instrument of the state's regional policy. It provides various incentives for economic entities operating in a selected location, supporting both businesses and the region's development. This paper emphasizes the significance of the SSEZ in the context of the Podlaskie Voivodeship's development as a peripheral region. Peripherality is an ambiguous and complex concept (Proniewski, 2014). The peripherality of regions can be considered, among other things, from a spatial perspective (when a region is characterized by its distance from economic centers and poor transport accessibility resulting from difficult geographical or political conditions) and from a socio-economic perspective (when a region is characterized by low economic development, lack of capital, and outflow of labor resources). Peripherality is also important in socio-demographic terms, which is related to low population density, depopulation, an aging population, and the migration of young and educated people (Miszczyk, 2010).

The study provides a detailed description of the SSEZ's functioning, focusing on its impact in the peripheral region, including the number of permits/decisions issued, the size of investments, and the level of employment. The local level was also taken into account, showing the various effects of the zone on local development, which is clearly underrepresented in the literature (Stojčić et al., 2022). Existing studies on the operation of SSEZs in Poland (Ambroziak, 2009) focus on descriptive analyses based on case studies (Ciżkowicz et al., 2015), the objectives of their creation (Cicha-Nazarczuk & Nazarczuk, 2017), but they do not analyze the actual impact of the zones on improving the overall situation in the region and on the local market. The aim of the study was to determine the importance of the Suwałki Special Economic Zone for the socio-economic development of the Podlaskie Voivodeship. The following research tasks were formulated: (1) to present economic zones as an instrument of interventionism in regional development; (2) to identify the effects of the SSEZ on the development of the voivodeship:

permits/decisions granted, investment outlays, jobs created, and investment structure; (3) to determine the significance of the SSEZ in the local context, i.e., in the assessment of employees working in a company operating within the zone and the authorities of one of the communes in which the zone is located. It is assumed that the impact of SSEZs on the development of peripheral regions is multidimensional; in addition to land use and job creation, there are other effects that are important for local development.

SPECIAL ECONOMIC ZONES IN POLAND AS AN INSTRUMENT FOR SUPPORTING REGIONAL DEVELOPMENT

Special economic zones (SEZs) in Poland were established based on the act of 20 October 1994 on special economic zones (Ustawa z dnia 20 października 1994 r. o specjalnych strefach ekonomicznych). This act defines SEZs as separate areas within the country where economic activity can be conducted on preferential terms. The creation of SEZs in Poland was a response to the challenging socio-economic situation that followed the political transformation in 1989 (Ciżkowicz et al., 2015), which included high unemployment rates (Jensen & Winiarczyk, 2014). Some regions adapted to the new conditions, but in many others, economic development problems grew, including high unemployment, business failures, and a lack of capital. Regional and local authorities were unable to solve these problems on their own, prompting the state to intervene and create SEZs.

The creation of privileged economic zones in Poland is a manifestation of state interventionism in development processes (Żminda et al., 2017), which is understood as a system of state economic policy based on direct government involvement in the economy on a macro scale, utilizing a variety of instruments. The main tools of interventionist policy include, among others: state investment projects aimed at increasing employment without increasing the supply of goods and services, subsidies to unprofitable enterprises, protectionism in foreign trade, and monetary and fiscal policy (Winiewicz-Bosy, 2009). A special economic zone is a designated area within a country where economic entities are subject to specific eco-

conomic conditions that are more favorable than those generally applicable in the country (Budzanowski, 2008; Buonocore et al., 2023). From an economic perspective, the zone is one of the instruments of the state's regional policy, which establishes various facilities for domestic and foreign companies to operate in a designated location. It is therefore a form of state aid for both regions and entrepreneurs (Cieśliewicz, 2012). On an international scale, SEZs are geographically separate areas managed by autonomous entities that offer favorable investment conditions (Zioło, 2009; Arbolino et al., 2026). SEZs vary in size, structure, objectives, and management models, including industrial, commercial, technological, and free customs zones. Originally, SEZs were established for a period of 20 years from the date of their establishment; however, this term was later revised, and according to current assumptions, SEZs will operate in Poland until the end of 2026 (Informacja, 2024). Various scenarios for supporting economic activity in the regions are being considered for the future, including extending the operation of economic zones or integrating them with other forms of investment support.

The purpose of establishing SEZs was to accelerate economic development in Poland by attracting foreign investors, mainly through the creation of preferential tax policies, especially in regions perceived as unattractive for investment (Żminda et al., 2016). The assumption was that economic development could be supported by developing specific areas of economic activity, introducing new technological solutions, and expanding exports. The zones were also intended to reduce growing structural unemployment and contribute to the effective use of existing industrial infrastructure (Kryńska, 2000), improve the competitiveness and innovation of the national and regional economy (Nelec & Prusek, 2006), and promote integration with international markets. A significant impact on quantitative and qualitative changes in the areas covered by the zones was assumed (Miłaszewicz, 2011). Previous studies (Ambroziak, 2009) show that, in practice, SEZs have a significant impact on regional economic development in Poland (Łukaniszyn-Domaszewska et al., 2023), contributing to increased regional competitiveness and supporting the restructuring and modernization of industry.

The first economic zone in Poland, Euro-Park Mielec, was established in 1995 on the site of a former aircraft factory, which had previously been severely affected by the reforms (Siudak & Wątorrek, 2011). By 1 January 1998, 17 SEZs had been established in Poland, but one zone did not commence operations (special economic zones in Częstochowa), the Mazovia Special Economic zone was liquidated due to a lack of investor interest, and two zones (Tczew and Żarnowiec) were merged. Currently, there are 14 economic zones covering 22,949.5 ha (as of 31 December 2024). It should be emphasized that the act on special economic zones (Ustawa z dnia 20 października 1994 r. o specjalnych strefach ekonomicznych) has been amended numerous times, primarily to adapt its provisions to European Union standards and changing economic realities. However, the main objectives of the SEZ remain unchanged. Management of the zone may be entrusted only to a joint-stock company or a limited liability company in which the majority of votes at the general meeting or shareholders' meeting are held by the State Treasury, regional government, or other managing entity. Subzones are also created within SEZs and on the land they manage. Each zone operates in accordance with a development plan drawn up by the minister responsible for the economy (currently the Minister of Development and Technology). Business activity in an SEZ is permitted through a permit, an administrative decision issued by the zone's management board on behalf of the relevant minister. The permit entitles entrepreneurs to enjoy the privileges of the zone, i.e., relief and exemption from local taxes (on real estate), total exemption from income tax for 10 years, and partial exemption for the remaining period, as well as access to land prepared for investment. The permit specifies detailed conditions regarding employment, investment, deadlines, and eligible costs. Support and rules for granting public aid depend on the location of the investment and the size of the enterprise.

A significant change was the establishment in 2018 of the Polish Investment Zone (PIZ) (Ustawa z dnia 10 maja 2018 r. o wspieraniu nowych inwestycji), which extends the existing SEZs to the entire country. In addition to the territorial expansion, new rules for investment support were introduced. Instead

of the permits they have received so far, entrepreneurs receive decisions on support. The support decision specifies the conditions related to the investment, including minimum investment expenditure, the number of new jobs, and the qualitative and quantitative criteria that the entrepreneur must meet. Decisions are issued for a fixed period of up to 15 years. Public aid may range from 10% to 70% of eligible costs, depending on the size of the enterprise and the location of the investment. Until the end of 2026, both systems will operate in parallel. The empirical part of the study considered both the effects of the SEZ and the PSI on the SSEZ under study.

METHODS AND CHARACTERISTICS OF THE RESEARCH AREA

The following data sources were used in this study: data obtained from the Suwałki Special Economic Zone (current as of 30 November 2023), data published by the Ministry of Development and Technology 2012–2023 (Informacja, 2012–2024), and data obtained from the Local Data Bank (Statistics Poland). Additionally, the results of surveys conducted in 2024 among SaMASZ sp. z o.o. employees, a company operating in the Suwałki Special Economic Zone in the Zabłudów commune, in the machinery industry, were utilized. The company was deliberately selected for the study due to its significant importance for the region's economy and the local labor market (over 800 employees in 2024). The surveyed company manufactures agricultural machinery and has been operating on the market since 1984 (including in the SSEZ on the basis of a permit from 2016) and implements investments in innovative solutions concerning, among others, production processes and manufactured products. Information obtained from company employees can supplement knowledge about effects of the SSEZ's activities and its impact on local and regional development. A survey using a computer-assisted web interview (CAWI) was conducted among all company employees in 2024. Results were obtained from 34 people, i.e., approximately 4.3% of the total number of employees in the surveyed company, which limits the possibility of generalizing the results. To understand the effects of the SSEZ from the local government's perspective, a CAPI interview

was conducted in 2024 with a representative from the local authorities, specifically the commune located within the SSEZ area.

The study covers the Podlaskie Voivodeship, located in the northeastern corner of Poland (Fig. 1). The region boasts unique natural and cultural assets, as well as significant development potential; however, it has been facing numerous economic and social challenges for years. The Podlaskie Voivodeship, along with four other voivodeships, is part of Eastern Poland, a macroregion identified by the European Commission in 2007 as requiring special financial support under the Cohesion Policy. This is evidenced by the low GDP (in 2007, GDP per capita was 74.1% of that of Poland, and in 2002, it was 77.6%) and high unemployment; the registered unemployment rate in the Podlaskie Voivodeship in 2007 was 10.4% (Statistics Poland). In addition to its peripheral location in relation to the central and western parts of the country, the region is characterized by underdeveloped transport infrastructure, a low degree of industrialization, and insufficient investment, which affects the region's competitiveness compared to other voivodeships. The area is peripheral both spatially, as it is located on the external border of the country and the European Union, and socio-economically, due to factors such as lower GDP per capita indicators compared to other voivodeships, low investment attractiveness, and issues with population outflow. The Suwałki Special Economic Zone (SSEZ) has been operating in the Podlaskie Voivodeship since 1996. Its scope covers the entire Podlaskie Voivodeship, two counties of the Warmian-Masurian Voivodeship (Ełk and Gołdap) and four counties of the Mazowieckie Voivodeship (Łosice, Ostrów, Sokółów, and Węgrów). Both the area of the SSEZ and the level of development underwent changes during the analyzed period. In 2023, its area was 662.9506 ha, and the share of developed areas was 85.8% (Informacja, 2024).

The establishment and operation of the SSEZ is an important instrument for supporting and stimulating regional economic development by offering preferential conditions for investors, including tax breaks and other forms of support, which in turn is intended to assist in the creation and development of businesses, the creation of new jobs, and the development of infra-

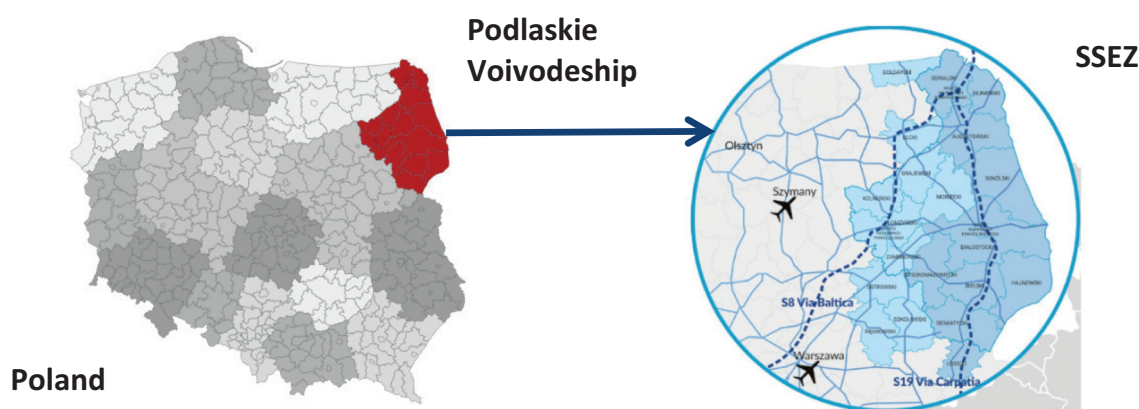


Fig. 1. The scope of the Suwałki Special Economic Zone (SSEZ)

Source: own study based on Polish Investment and Trade Agency (n.d.) and Suwałska Specjalna Strefa Ekonomiczna S.A. (n.d.) data, <https://www.paih.gov.pl/>; <https://ssse.com.pl/>

structure. The SSEZ is a partnership project involving both state and local authorities, which hold almost 60% of the shares in the company. Among the entities conducting business activity in the zone, micro, small, and medium-sized enterprises dominate, with large enterprises accounting for only 28% of the total.

RESULTS AND DISCUSSION

Regional perspective

To assess the effects of the SSEZ, an analysis of indicators for the years 2012-2023 was conducted, including the number of new and valid permits/decisions supporting business activity, the value of capital expenditure, and the number of jobs. The analysis of the data (Table 1) shows a stable increase in investment expenditure in the SSEZ, both on the basis of permits and decisions on investment support (since 2018). The decline in the number of valid permits since 2019 is a consequence of permits expiring by operation of law and the lack of new permits for operations in the zones. The SSEZ was characterized by a relatively high increase in investment expenditure compared to other zones and an increase in expenditure compared to the previous year (except for 2016). This indicates growing interest among companies in investing in the SSEZ and a positive impact on the economy of the Podlaskie Voivodeship. The effects of the SSEZ's activities

are evident in the labor market (Fig. 2). An analysis of changes and dynamics in retained and new jobs during the review period reveals positive trends. In 2023, 9,272 people were employed in the SSEZ. The number of jobs reported is related to the validity of permits; for example, in 2016, the decrease of 746 jobs was caused by the expiry of 27 permits. Another decrease occurred in 2022–2023, which was due to a reduction in employment, caused in part by an increase in inflation in Poland and, consequently, an increase in business costs.

When analyzing the number of jobs in the SSEZ, it should be borne in mind that investments made in these areas create demand for employment in the vicinity of the zone (Żminda et al., 2017) – demand is generated for various types of services: financial services for companies, logistics and transport services (including local companies), and a revival in construction services due to the need to develop and prepare the land for investment and the construction of new facilities (Krzemiński, 2009). Furthermore, investments in zones have multiplier effects (Ambroziak, 2009) as they increase local demand for other types of services, such as catering, security, workwear laundry, or various outsourcing services (Godlewska-Majkowska, 2009), which may not yet be developed in peripheral regions. It can therefore be concluded that the actual number of jobs created through special economic zones is significantly higher than the statistical data suggest.

Table 1. Effects of the functioning of the Suwałki Special Economic Zone in 2012–2023

Specification	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Number of valid permits	65	71	81	89	79	92	106	96	89	85	83	78
Number of new permits (or support decisions since 2018)	10	11	16	8	19	15	23	14	20	36	13	23
Capital expenditure incurred [PLN million]	1,581	1,608	1,745	2,079	1,941	2,500	2,877	3,042	3,187	3,367	3,533	3,684
Growth rate (previous year = 100%) [%]	99	102	109	119	93	129	115	106	105	106	105	104

Source: own study based on information on the implementation of the act on special economic zones as of 31 December 2012–2023 (Informacja, 2012–2024) and data obtained from SSEZ.

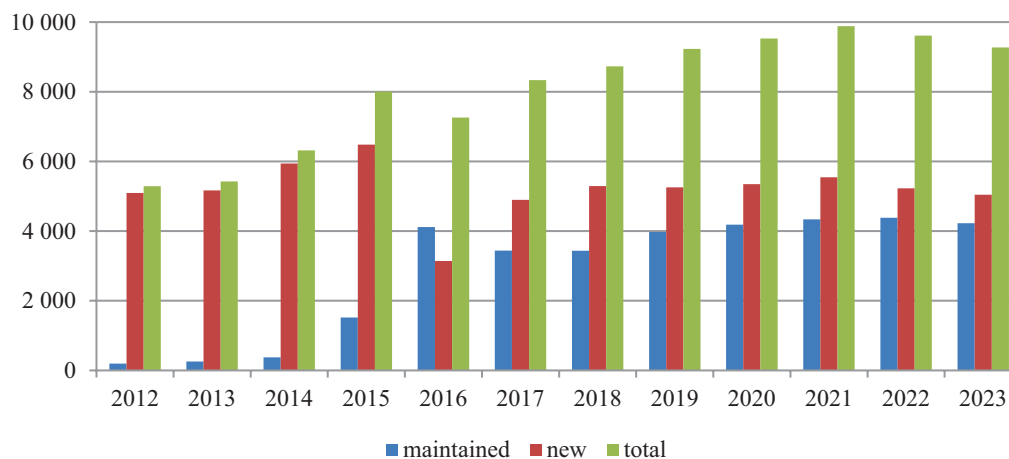


Fig. 2. Number of jobs in the Suwałki Special Economic Zone in 2012–2023

Source: own study based on information on the implementation of the act on special economic zones as of 31 December 2012–2023 (Informacja, 2013–2024) and data obtained from SSEZ.

Between 2012 and 2023, the share of Polish capital in the SSEZ’s investment structure increased significantly from 49.5% to 78.6%, indicating the strong involvement of domestic investors in the zone’s development. Among the largest Polish investors, in 2023, there were: Tanne, Pfeleiderer MDF Grajewo, Padma (from the wood industry), and Bison (metal products). In terms of capital invested, Germany and Denmark were among the leading investor countries until

2017. Since 2018, the share of German capital has decreased in favor of other countries, i.e., Sweden and Denmark, whose shares were 9.3% and 7.7%, respectively. The largest Swedish investor is Rosti Poland (plastics), while the largest Danish investor is Rockwool Polska (building materials). The industry structure of investments in the SSEZ is dominated by companies from the wood industry (Fig. 3), whose share ranges from 30.5% to 36.4% of the total value

of investments in this zone. Other dominant industries include the manufacture of rubber and plastic products, as well as metal products.

The activities of the SSEZ are also noticeable from the perspective of technical infrastructure development in the region, especially during the initial stage of operation (Konopelko, 2013). The most significant investments carried out by SSEZ between 2012 and 2023 include the construction of storm-water and sanitary sewage systems in Suwałki, as well as the extension of local streets. Larger infrastructure projects are typically carried out in cooperation with local governments and utility providers, such as the construction of sanitary sewage systems, water supply networks, telecommunications networks, road surfaces, sidewalks, bicycle paths, parking lots, and lighting in Białystok between 2016 and 2019. The city of Białystok has developed investment areas using funding from the Regional Operational Program of the Podlaskie Voivodeship for 2014–2020. The investment significantly contributed to attracting investors to the SSEZ, as well as increasing the number of investments in the region and creating new jobs.

The significant effects of the SSEZ's activities in the context of peripheral region development include promotional activities that focus on organizing training courses, seminars, and webinars aimed at both entrepreneurs operating within the zone and potential investors. Representatives of the zone regularly participate in national and international investment fairs and economic conferences. Brochures, folders, reports,

and other promotional materials are prepared, containing information about available investment areas, tax breaks, and the benefits of investing in the zone. SSEZ conducts promotional activities on the Internet, managing its website and social media profiles, which facilitate communication with investors and promote the zone's achievements. This influences the perception of the Podlaskie Voivodeship as a business- and investment-friendly location, which in the long term may improve its attractiveness and investment competitiveness (Walkiewicz, 2017).

SSEZ also conducts extensive activities in the field of vocational education, cooperating with secondary schools (vocational schools, technical schools) in Suwałki and Białystok, as well as with universities, including the Szczepanik State Higher Vocational School in Suwałki and the Białystok University of Technology. The most important initiatives implemented in cooperation with schools include: scholarships for students of technical fields; organization of classes and lectures for pupils and students to encourage young people to consciously plan their educational and professional paths; support for regional competitions aimed at promoting vocational education, and the organization of press conferences promoting vocational education with the participation of school representatives. In addition, SSEZ co-organizes career, job, and education fairs, and companies from the zone sponsor selected fields of study at vocational and technical schools.

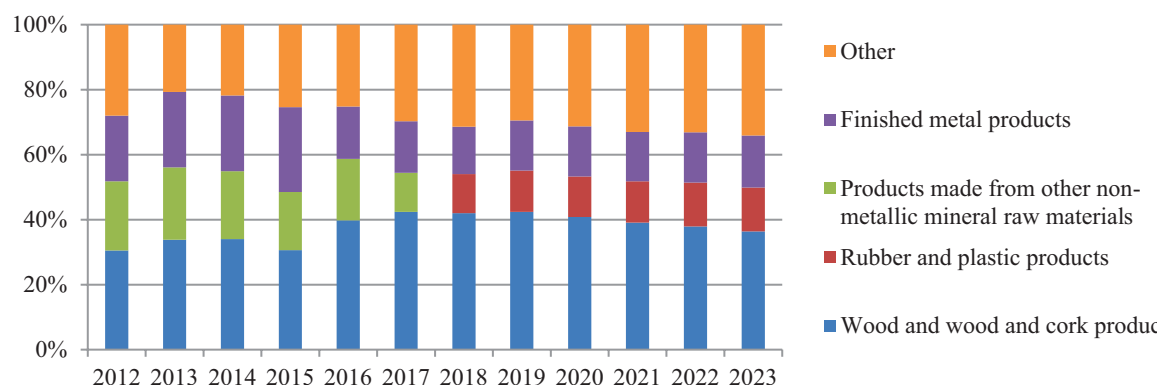


Fig. 3. Industry structure of investments by leading industries in the Suwałki Special Economic Zone in 2012–2023

Source: own study based on information on the implementation of the act on special economic zones as of 31 December 2012–2023 (Informacja, 2013–2024) and data obtained from SSEZ.

SSEZ supports the development of clusters by being a member of the following clusters: Metalworking Cluster (Evoluma Industrial Cluster) and Polish Construction Cluster (status of National Key Clusters) as well as Grajewo Entrepreneurship Cluster and Polish Wood Cluster. Clusters play a crucial role in integrating businesses, scientific institutions, and research and development units, promoting the exchange of knowledge and the implementation of innovative projects in the region.

Local perspective

A survey conducted among employees of a company operating in the SSEZ was completed by 34 people, 83% of whom were men. The respondents were mainly city dwellers (65%), 47% had secondary education, and 41% had higher education.

Employees of the surveyed company were asked for their opinion on the importance of the SSEZ's functioning and its impact on the living conditions of the inhabitants of the Podlaskie Voivodeship, as well as the expected effects that the zone should generate. The results are presented in Figure 4.

According to the surveyed employees, the SSEZ has had a decisive impact on the local labor market, the development of technical infrastructure, and the development of new technologies. The zone is therefore perceived

as an effective tool for job creation, which is a key factor in regional development. The respondents also pointed to the significant importance of the zone for the growth of the voivodeship's residents' incomes and their living conditions. However, the results obtained may suggest that the economic benefits of the SSEZ's activities are not equally felt by all residents. The respondents also note the impact of the SSEZ's activities on shaping the image of the Podlaskie Voivodeship.

According to the surveyed employees (67.6%), salaries in companies operating within the zone are not higher than in companies outside the zone. The lack of differences may result from the wage policy of specific companies, the specifics of the regional labor market, or the type of industry. The respondents indicated that working conditions in the SSEZ are not better than outside it (44.1% of responses, with 26.5% having no opinion). A total of 91.2% of respondents are satisfied with their current employment and expressed their willingness to be re-employed, which may indicate good working conditions, attractive remuneration, opportunities for professional development, or a positive work atmosphere.

Respondents were asked whether, in their opinion, the SSEZ had fulfilled its role in accelerating the economic development of the Podlaskie Voivodeship. The vast majority of respondents, i.e., 91.2%,

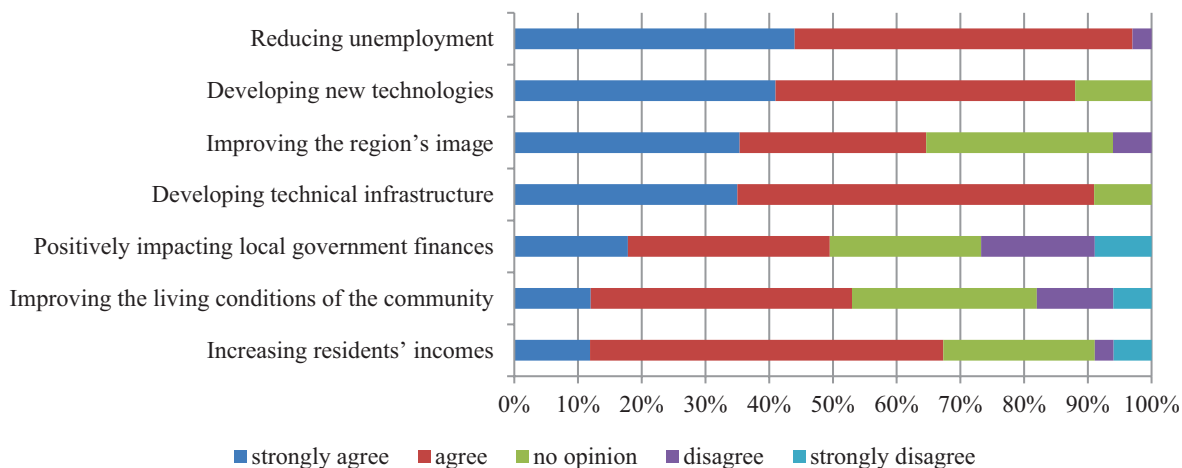


Fig. 4. The impact of the Suwałki Special Economic Zone on the development of the Podlaskie Voivodeship as assessed by company employees

Source: own research.

stated that the SSEZ had fulfilled its role, which gives a positive image of the SSEZ and its impact on the region's development.

Respondents were asked to indicate other effects of the SSEZ. The results obtained earlier (Fig. 4) were confirmed by the answers to this question, as 74% of respondents indicated a reduction in unemployment or the creation of new jobs. In addition, the following effects were noted: attracting new investors and promoting business development, new investments, technological advancements (Pastusiak, 2011), subsidies supporting business development, increased tax revenues, and the expansion of technical and road infrastructure. This confirms the conclusions from the literature that the effects of the zones are mainly positive, although not always very strong (Hirasuna & Michael, 2005; Ciżkowicz et al., 2015). It should be emphasized that negative effects associated with the functioning of zones were also noted (Billings, 2009), although these were mentioned much less frequently (21% of respondents). These included a lack of or reduction in tax revenues to the budget, the concentration of companies in one place and environmental pollution, unfair competition, companies "escaping" to economic zones, and increased car traffic.

An interview with a representative of the local government of a commune within the SSEZ also revealed various effects of the SSEZ's operation at both regional and local levels. From the local government's perspective, the SSEZ's impact on the quality of life of residents through the development of technical infrastructure (roads, power grids, and water supply networks) is significant. However, it should be remembered that the investments made in connection with the SSEZ generate additional maintenance costs, which require local governments to carefully plan and manage local finances. From the perspective of local authorities, it is crucial to increase revenue from taxes and other fees, which strengthens local government budgets (even despite initial tax exemptions for entrepreneurs) and provide long-term financial benefits through various redistribution mechanisms. The research also pointed to the introduction of innovative technologies by companies, which contributes to raising the technological level of the Podlaskie Voivodeship. Employees gain new skills, which increases their ability

to compete in the market. The commune authorities have drawn attention to the potential risk of excessive dependence of entrepreneurs on large economic entities, which is particularly dangerous in situations where a large entity leaves the region, such as due to changes in economic or political conditions. Currently, due to the geopolitical situation and the war in Ukraine, some entities located in the SSEZ have lost a significant portion of their markets in Eastern Europe, which may have implications for companies cooperating with them.

The results obtained in terms of effects confirm the findings of other authors. However, it is worth emphasizing that, despite the dynamic development of economic zones in Poland over recent years, there remains relatively little empirical research analyzing the actual effects of zones on development at the regional and local levels. Most of the available literature is limited to basic statistical descriptions or determines the impact of SEZs on direct employment and unemployment levels (Cicha-Nazarczuk & Nazarczuk, 2017). The results confirm the conclusions from the literature on the significant role of SEZs in employment growth (Ciżkowicz et al., 2015), at the local level (Szmidt, 2016), and in attracting foreign investment (Jensen & Winiarczyk, 2014; Łukaniszyn-Domaszewska et al., 2023). Based on the research, it can be concluded that the SSEZ has a positive impact on the development of the Podlaskie Voivodeship, which is a peripheral region. The impact of the zone can be observed on multiple levels of local development, confirming the initial assumption. The SSEZ contributes, among other things, to economic growth, job creation, infrastructure development, and the strengthening of human capital (Hajduga, 2014). It should be emphasized that the activities of the SEZs are positively perceived at the local level; our own research shows that residents and local authorities are aware of the effects of their operation. To capture the full picture of the impact of SSEZs on the region under study, it is necessary to consider a broader range of enterprises. When analyzing the results of the research, it should be emphasized that some authors suggest that the strength of the effects of economic zones depends both on pre-existing regional economic conditions (Goss & Phillips, 2001;

Mayneris & Py, 2013) and on the specific characteristics of the zones (Bondonio, 2003; Cicha-Nazarczuk & Nazarczuk, 2017; Frick & Rodríguez-Pose, 2023). This highlights the necessity of ongoing monitoring of the functioning of SEZs and their impacts, including any negative effects (Typa, 2016), within the context of regional development.

CONCLUSIONS

The establishment of the Suwałki Special Economic Zone in the Podlaskie Voivodeship aimed to attract investment, create new jobs, and improve the overall economic situation of this peripheral region. Companies operating within the SSEZ have had a significant impact on job creation and on stabilizing the local labor market. Residents now have greater employment opportunities in various industries, not only within the zone, but also with partners and cooperators operating outside the zone. Additionally, foreign investment has emerged in the region, indicating that investors appreciate the region's attractive investment conditions. The investments carried out within the SSEZ necessitated expanding technical infrastructure, which, in the long term, may contribute to the further development of the region and enhance its competitiveness. The research has revealed that the benefits of the SSEZ are also visible at the local level and are multidimensional. In addition to the effects on the labor market, these initiatives include enhancing the region's image as an attractive investment destination, promoting the development of vocational education in the region, and increasing the income of residents and local government units.

The study has certain limitations, including limited access to data describing the effects of the zone. Our research allows us to draw conclusions from a local perspective, but the small sample size analyzed is a significant limitation that prevents us from generalizing the results to the entire SSEZ. In addition, the study utilized data for the SSEZ, which covers an area slightly larger than the Podlaskie Voivodeship. Future studies should focus on further monitoring the effects of economically privileged areas, covering a wider local scope, e.g., more enterprises, which may help shape new, effective instruments to stimu-

late the socio-economic development of peripheral regions. It is also important, especially for the region near Poland's eastern border, to consider the context of the war in Ukraine and its impact on companies operating in the SSEZ.

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SPECJALNE STREFY EKONOMICZNE JAKO INSTRUMENT WSPARCIA ROZWOJU REGIONÓW PERYFERYJNYCH W POLSCE – PRZYKŁAD WOJEWÓDZTWA PODLASKIEGO

STRESZCZENIE

Cel: Występowanie dysproporcji w rozwoju społeczno-ekonomicznym regionów w Polsce stanowi kluczowy problem współczesnej gospodarki. W 1994 roku utworzono specjalne strefy ekonomiczne, będące wyodrębnionymi obszarami, na których działalność gospodarcza może być prowadzona na preferencyjnych warunkach. W pracy pokazano znaczenie działania Suwalskiej Specjalnej Strefy Ekonomicznej (SSSE) w kontekście rozwoju województwa podlaskiego jako regionu peryferyjnego. **Metody:** Przedstawiono szczegółowo funkcjonowanie SSSE, koncentrując się na efektach działania SSSE, w tym liczbie wydanych zezwoleń, wielkości inwestycji oraz poziomie zatrudnienia. Wykorzystano dane statystyki publicznej oraz dane pozyskane z SSSE za lata 2012–2023, a także wyniki badań ankietowych (CAWI) przeprowadzonych w 2024 roku wśród pracowników jednego z przedsiębiorstw działających na terenie SSSE oraz wywiadu (CAPI) z przedstawicielem władz lokalnych. **Wyniki:** Wyniki badań wskazują, że SSSE miała znaczący pozytywny wpływ na rozwój gospodarczy województwa podlaskiego, m.in. przyciągnęła liczne inwestycje, które przyczyniły się do wzrostu zatrudnienia i poprawy infrastruktury technicznej. Korzyści z działania SSSE są widoczne na poziomie lokalnym. **Wnioski:** Inwestycje realizowane w specjalnych strefach ekonomicznych przynoszą efekty mnożnikowe poprzez generowanie zwiększonego lokalnego zapotrzebowania na inne rodzaje usług. Monitorowanie efektów działania obszarów uprzywilejowanych gospodarczo może pomóc w przyszłości w kształtowaniu skutecznych instrumentów pobudzania rozwoju społeczno-gospodarczego regionów peryferyjnych.

Słowa kluczowe: interwencjonizm, Suwalska Specjalna Strefa Ekonomiczna, rozwój regionalny, region peryferyjny, województwo podlaskie

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