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Usage of AI in Sustainable Knowledge Management and Innovation Processes; Data Analytics in the Electricity Sector

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Abstract: Successful organisations prioritise product quality and customer satisfaction. Non-financial indicators are crucial for measuring performance, requiring specific financial and technology management knowledge. Effective knowledge management and entrepreneurial activity significantly impact performance, vital to the country's economic factors. Electricity is crucial to society's development. Renewable energy sources such as solar, wind, hydropower, and biomass can generate sustainable electricity. Managing environmental, social, and economic aspects is essential for sustainable societal and virtual development. In this study, the central element of novelty is associated with the dependent variable Nominal Labour Productivity per Employee. This research shows that effective knowledge management impacts a company's business performance. Based on secondary data from various sources, we have used factor analysis to assess the interrelationship between the factors and econometric dimensionalities. Accompanied by this econometric approach, the research methodology aims to present hybrid models based on econometric techniques and artificial intelligence (AI) networks. Based on the principal component method analysis results, we show the interdependence of 30 variables in the micro and macro environment. The new components of the correlated variables show how knowledge and innovation are related to the economic performance of society, and nominal employee productivity is a valuable indicator for measuring economic efficiency. Nevertheless, AI, a knowledge management product, provides helpful comments on the econometric results.

Keywords: artificial intelligence; electricity; innovation; knowledge; sustainability

JEL Classification: C38; M530; O120

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1. Introduction

Modern organisations are recognising the importance of non-financial indicators in measuring business performance. These indicators are calculated differently and require expertise in financial and technology management. An organisation's success depends on having sufficient personal and machine knowledge and engaging in entrepreneurial activities. These factors significantly impact economic factors within the country. Electricity consumption is a critical macroeconomic factor contributing to various sectors' growth and development. Electricity and sustainable development are closely intertwined since a reliable electricity supply is necessary for society's economic and social development. One sustainable option for electricity generation is through renewable energy sources, including solar, wind, hydropower, and biomass. In this context, knowledge and innovation play a significant role as they are critical factors in an organisation's sustainable development. Effective environmental, social, and economic management provides organisations with the necessary information and skills.

Lately, companies have been paying attention to research and knowledge management, realising that knowledge is a critical factor for growth or even the existence of a company. Knowledge has always been passed down from generation to generation. Organisations that have started to engage in knowledge management regularly have found that they possess much more knowledge than they use. Our motivation for this research comes from the increasing emphasis of the European Union (EU) on sustainable development, primarily in the energy sector.

The research aim is to demonstrate that effective knowledge management can influence a company's business performance and efficiency. Modern organisations also focus on non-financial indicators to measure business performance, such as satisfaction, user loyalty, employee motivation, intellectual capital, etc. All these factors impact the economic value added, marketing value-added issues, business performance value, and, hence, the economic growth of the entire country.

Entrepreneurial activities significantly impact the economy by establishing economic foundations and providing new job opportunities. As a case study in this research, Elektro Ljubljana has 878 employees and is classified as a significant Slovenian company. It owns the electric distribution infrastructure and is part of Slovenia's power system. The company combines a responsible approach to the future with technological and societal aspects. Through innovative solutions, a smart grid, and quality, they aim to remain a leading partner in energy development. Elektro Ljubljana is a critical player in green energy. Electric power is a crucial macroeconomic factor, representing one of the fundamental energy sources enabling economic functioning. It is utilised in various sectors, contributing to their development and growth. Demand for electric power is an indicator of economic activity. Higher demand for electrical energy indicates increased production and investments, leading to economic growth [1].

Using the Generative Pretrained Transformer (GPT-4) and factor analysis, we wanted to demonstrate that investment in technology and employee education at Elektro Ljubljana contributes to gross domestic product (GDP) growth, energy efficiency, and productivity. We compared 30 variables divided into micro and macro environments through advanced hybrid methods. Accompanied by GPT-4 with the principal component method, we illustrated the interdependence of variables.

The research demonstrates that effective knowledge management affects a company's business performance. We are also interested in understanding the impact of knowledge and innovation variables on nominal employee productivity, as all new technological activities (GPT-4) result from the companies' knowledge processes. Placing individuals at the forefront in a suitable environment allows them to use their knowledge, develop their talents, and contribute to the success of society.

The paper's organisation follows a clear structure. The materials and methods will be presented after the introductory section, followed by an in-depth literature review. Subsequently, the results will be unveiled, culminating in a discussion and conclusion to conclude the manuscript.

2. Theoretical Consideration of Knowledge

2.1. Management of Intellectual Capital

Intellectual capital refers to the collective knowledge, experiences, ideas, processes, and other intellectual resources a company uses to create value and gain competitive advantages. Intellectual capital comprises three main categories: human, structural, and customer relations [2,3].

Human capital pertains to employees' knowledge, experiences, skills, abilities, and intellectual resources. It includes knowledge acquired through formal education training and experience gained while working. Human capital is divided into employees' competencies, attitudes toward work, and intellectual flexibility. Structural capital refers to the company's resources that support value creation, such as databases, patents, trademarks, information systems, business processes, and other intellectual assets. According to Možina, structural capital is the organisation's relationship with stakeholders and its ability to innovate and develop the organisation.

Companies can choose various ways to measure and manage their intellectual capital, such as using employee assessment systems, knowledge management, market research, and competitive analysis. Effective intellectual capital management can assist companies in improving product or service quality, customer satisfaction, increasing innovation, and achieving long-term success [4,5]. Management of intellectual capital (IC) is also referred to as Intellectual Capital Management (ICM). It involves companies' processes, techniques, and strategies to manage their intellectual capital efficiently. According to [6], measurement and valuation are different approaches based on market value, use of indicators, added value, profitability, knowledge balance, etc. Intellectual Capital Management involves identifying essential intellectual resources and assets within the company, such as developing processes for gathering, storing, and exchanging intellectual capital; implementing a system for evaluating and valuing intellectual capital in the company; utilising knowledge management tools, such as databases, document management systems, project management systems, and other information techniques; and implementing procedures for knowledge sharing and collaboration [7,8].

Measuring intellectual capital is crucial for understanding the value and success of a company and is carried out through various quantitative and qualitative methods. This includes analysing financial statements, where the company examines the portion of investments directed towards intellectual capital, analysing employee performance to assess their effectiveness and ability to contribute to innovations, analysing the costs of education and training to determine the impact of these investments on the quality and scope of intellectual capital, analysing the organisation's structure and processes that can affect the creation and management of intellectual capital, employee satisfaction surveys to assess the effectiveness of intellectual capital management, and the availability of tools and knowledge for information exchange, and analysing intellectual property, enabling the assessment of value, including trademarks, patents, copyrights, and other intellectual rights [9,10].

2.2. Description of Previous Empirical Research

Measuring intellectual capital can help companies understand their strengths and weaknesses when developing a strategy for managing intellectual capital and where they can improve for competitiveness and business success.

Knowledge plays a crucial role in a company's success. Employees with appropriate knowledge can perform their tasks more efficiently, leading to improved product or service quality and increased company revenue [11]. Moreover, knowledgeable employees can assist in innovation, developing new products and services, and process enhancement within the company [12]. In modern society, knowledge is becoming a commodity, not only a right but a necessity for everyone, no longer belonging solely to educational institutions but to society as a whole [13]. A company has the opportunity to ensure that employees have the necessary knowledge by training and educating them. Employee education includes formal training programmes such as courses, seminars, workshops, or on-the-job training.

Additionally, a company can encourage employees to exchange knowledge and experiences by organising internal meetings where employees can learn from each other. A company should create a learning culture that encourages employees to learn and develop [14]. A learning culture may involve rewarding employees for acquiring new skills or sharing knowledge.

Moreover, a company can encourage employees to explore new ideas and problem-solving innovatively. This makes the company more competitive and thriving in the market [15]. Strategic knowledge management is established for learning organisations that focus on people, their behavioural characteristics, and behaviours [16]—management resorts to direct measurement and objective assessment. The basis for proper measurement and control are few, understandable, and transparent criteria that form a balanced set of measures for ongoing use [17]. Knowledge identification in a company refers to the processes that enable knowledge and employees' experiences to be correctly recorded and developed within the company. When identifying knowledge within the company, the company must have an appropriate culture that encourages knowledge and experience sharing and has the proper systems and processes for collecting, organising, and sharing knowledge [18]. With this, the company can utilise employees' knowledge and experiences to improve operations, increase efficiency, and provide competitive advantages in the market. Identifying knowledge within the company involves multiple steps, such as identifying fundamental knowledge and experiences, collecting and organising ability, sharing knowledge, and preserving it. Identifying fundamental knowledge and experiences helps the company recognise which knowledge is crucial for successfully implementing business processes. This is followed by collecting and organising knowledge, which can be carried out through systems such as knowledge bases and an internal portal [19].

In the next step, the company focuses on knowledge sharing, where the collected knowledge is made available to other employees through education, training, or mentorship. It is essential to ensure the speed and quality of knowledge transfer, with the mode of transfer depending on the type of knowledge–implicit knowledge is transferred through personal communication, while explicit knowledge is most often transmitted through technology [20–22]. Finally, the company must ensure the preservation of knowledge, even when employees leave the organisation. This can be achieved by documenting processes and practices and providing access to this information to those who need it. Protecting knowledge becomes an essential knowledge management task, as found in the literature review manuscript [23].

2.2.1. Educational Management

Educational management encompasses all four functions of general management, which include understanding the current development of human resources and identifying differences between the actual and desired situation to study the needs and implementation of educational activities in the organisation (effective knowledge management as a foundation). Mihalič [24] highlights the critical tasks of modern educational management as the needs of employees, efforts to harmonise interests, intensive benchmarking comparison, a system of continuous learning, training to cope with rapid changes, and measuring the actual effects of education on added value (effective knowledge management as a foundation). The modern manager develops and introduces new methods for continuously educating all employees designing concepts and methodologies for integrating knowledge management processes. The most important aspect is the involvement of the knowledge manager in preparing individuals' career plans, implementing annual strategies, and designing advancement and reward systems. The biggest challenge in introducing this practice is achieving a psychological atmosphere; for example, innovative-thinking staff requires innovative leadership, as only it can motivate colleagues (effective knowledge management as a foundation) [25].

In the international context, increasing attention is paid to human resources but not their development [26]. Human resources involved in developmental research activities are crucial for maintaining competitiveness in the macro environment. This awareness is also present in a case study company, Elektro Ljubljana, as they create an environment that promotes the personal and professional development of employees, who are focused on the goal of reliable electricity supply, catering to more than a third of Slovenian users and in the year 2022, the average hours of succession planning and education in the organisational development in the company increased by 23% [25]. This served as an opportunity to evaluate the proportion of crucial developmental potentials concerning planning training hours for the previous year (annual resources) to assess the staff's share of development opportunities (resources, competencies) in individual developmental matrices. Elektro Ljubljana is also concerned with analysing the number of employees.

Additionally, acquiring knowledge is essential for personal and professional development. It is crucial for individuals to constantly seek new opportunities for learning and developing their skills to adapt to changes and demands in the job market quickly. Acquiring knowledge is when an individual obtains information, skills, and experiences. It is vital for encouraging and motivating employees' creativity [27,28].

Knowledge can be acquired formally or informally. Formal education includes education in schools, colleges, universities, and other educational institutions, while informal education occurs outside the school system. This includes reading books, listening to lectures, watching videos, and participating in various workshops. Individuals also acquire knowledge through work experience, where knowledge is transferred from older to younger employees, various mentoring programmes, or participation in projects and tasks that require new skills. We must not forget knowledge transfer from online sources and technology, which individuals gain from various websites, videos, courses, interactive games, and AI.

On the other hand, knowledge distribution in companies refers to knowledge transfer among employees, departments, and organisations [29]. This process is crucial for a company's success as it enables a faster and more efficient transfer of knowledge, which is used to improve processes and solve problems within the organisation. Knowledge distribution within the company is of paramount importance for successful operations. Creating a culture that encourages knowledge exchange, including implementing appropriate education programmes, anonymous knowledge transfer, and the use of technology, contributes to the development of innovation and the company's competitiveness [30]. Knowledge distribution in companies occurs through various means, including organising formal education programmes such as seminars, lectures, courses, and workshops to transfer new skills among employees. In addition, informal education programmes such as mentoring, occasional education, research, workshops, and group learning are also utilised based on structured approaches like knowledge bases, intranets, and internal communication channels. Technology, such as online platforms and social networks, is also valuable for knowledge sharing in companies. Modern companies promote a culture that encourages knowledge exchange by fostering open communication channels, collaboration, and teamwork [31].

Last but not least, using knowledge in companies refers to leveraging the knowledge that employees and the organisation possess to achieve business goals and improve the company's performance. Effective use of knowledge within a company can lead to better product and service quality, increased efficiency, process improvements, cost reduction, and enhanced competitiveness in the market. Authors [32] state that applying knowledge creates helpful value for the organisation, while AI recommends that companies invest in developing employees' knowledge and encourage knowledge exchange [33]. Applying knowledge within a company can be carried out in various ways, including connecting employees' knowledge with their experiences and shaping a knowledge base. Employees can use their knowledge and experiences for innovations that enhance efficiency. Systematic approaches, such as knowledge bases and applications, enable companies to utilise the knowledge of their employees and encourage a collaborative culture within the company [34].

Lastly, preserving knowledge within a company is crucial for the organisation's long-term success. Employees who accumulate a wealth of knowledge and experience while working in the company should pass it on to new generations of employees. Therefore, it is essential to understand knowledge preservation within the company as an ongoing process that does not end with an employee's position. Companies must ensure proper knowledge transfer in case of employee departure or organisational changes to maintain and enhance the organisation's long-term success [35]. Some methods for preserving knowledge within a company include documenting processes, mentorship, education, and knowledge sharing among employees. This enables new employees to learn quickly and gain practical experience within the company, fostering employee development [36]. We can say that in the economic business conditions, considerable attention is being given to companies that focus on human resources and promoting development related to technological advancements, as they are critical factors in maintaining competitiveness. This finding applies to Slovenia and the EU, whose ambition is to become the most competitive region in the world [37,38].

2.2.2. Sustainability and AI in the Organisation

AI shares similarities with the internet despite concerns that it may threaten human safety. However, it is essential to note that these fears are largely unfounded. While AI has the potential to revolutionise numerous industries and enhance our lives in countless ways, we must exercise caution and approach its development with a sense of responsibility and ethical consideration. By doing so, we can ensure that AI technology is leveraged for the greater good rather than causing harm or disruption. However, it offers numerous benefits to those in need, assuming that AI is necessary for a company to achieve its business goals, analyse requirements, have data availability, and for competitive advantage and development strategy [39]. Implementing AI in electric organisations can bring significant benefits and innovations, optimising energy processes such as more efficient distribution of electrical energy. Sustainability management in organisational leadership involves managing sustainable aspects such as the environment, society, and the economy. Sustainability management aims to create long-term value for the company, stakeholders, and the environment. Intelligent systems can enhance consumption adaptation, prevent power outages, and increase network efficiency [40–45].

One of the main advantages of using AI is its ability to process large amounts of data, which can assist in more efficient management of energy production, distribution, and consumption in the energy industry [46]. AI can optimise the operation of electrical grids and forecast energy needs, enabling better adaptation of energy production and distribution and improving overall energy efficiency [47]. Since AI consumes significant energy for its operation, its developers are already considering optimising algorithms and hardware, adjusting the architecture, reducing the amount of processed data, and performing multiple functions simultaneously, significantly reducing electricity consumption. In the future, we expect AI to play an even more significant role in ensuring sustainable development in various areas, as it can contribute to better natural resource management. It is also essential in developing more efficient and sustainable industrial processes, improving public services infrastructure, and planning more efficient and sustainable transportation systems, thereby reducing air pollution and improving the quality of life for residents.

Integrating knowledge into an organisation with the help of AI is possible and already an established practice in many organisations. AI can assist in automating processes, analysing data, predicting trends, improving decision-making, and much more. This can help organisations in effective knowledge management, better resource utilisation, and enhanced productivity. Additionally, AI can be integrated into a knowledge management system, enabling efficient capturing, storage, sharing, and utilisation of knowledge within the organisation. This leads to faster and improved decision-making, fostering innovation, and enhancing organisational success.

2.2.3. Introducing Sustainable Development into Elektro Ljubljana

Sustainable development and the success of organisations are closely linked, as an organisation's orientation towards sustainability affects organisational success. The success of organisations is measured not only in financial results but also in their contribution to sustainable development and achieving broader societal goals including new technologies. Consumers increasingly seek products and services that are environmentally friendly, socially responsible, and sustainably oriented. Energy efficiency and efficient resource usage are increasing. Sociologically responsible entrepreneurship leads to improved relationships with customers, employees, and the community and the establishment of long-term partnerships. Elektro Ljubljana successfully incorporates electric supply and renewable sources (RESs) into the distribution network. The main focus of the business is on distribution and its sustainability orientation. A development plan is prepared for 10 years within the framework of the new energy policy of the National Energy Climate Plan (NECP). Electrification, decentralisation, and digitalisation are development trends. In digitalisation, Elektro Ljubljana can boast that it has real-time insight into the actual state of the network on almost 17,000 km. Also, in 2022, all backlogs were eliminated due to the increase in the number of applications for the approval of solar power plants, additional employment, the redistribution of employees, and the streamlining of processes. With the revenue growth in the coming years from the trading activities, they will still be able to boast the electric vehicle charging infrastructure. As part of the green energy transition, the organisation is investing in upgrades [48].

For sustainable development within the organisation, it is crucial to have the collaboration and support of the organisation's leadership [49]. Clearly express the commitment to sustainable goals and ensure that these goals are critical in the organisation's strategy and long-term plans. A comprehensive organisation analysis involves identifying environmental, social, and economic challenges and evaluating existing practices, policies, systems, and the organisation's impact on the environment and society. One of the initial steps is to define sustainable goals that align with the specific needs and activities of the organisation. The goals should be ambitious and linked to sustainable development's environmental, social, and economic aspects. Concrete measures to achieve sustainable goals are a plan that should include tasks, responsible individuals, a timeline, and necessary resources for their implementation. The measures should focus on production, procurement, resource management, stakeholder relations, employee education, etc. Organisations can introduce employee awareness, understanding, and engagement through education and training, thus providing the knowledge, skills, and tools necessary to implement sustainability in practice.

Elektro Ljubljana is part of the electric power system and the largest of Slovenia's five electricity distribution companies. The company's core activities include managing, operating, and maintaining the distribution system and maintaining, constructing, and renovating the electricity distribution infrastructure in Slovenia's central and southeastern regions, covering 6166 km^2. Since 1 July 2007, the company has leased the electricity distribution infrastructure to the distribution system operator and provides contracted services. The company also manages the largest network of electric vehicle charging stations. The energy sector is undergoing a significant transformation, and the set national and global goals are highly ambitious. Elektro Ljubljana is a joint-stock company, with the Republic of Slovenia being the largest owner at 79.5%.

2.2.4. Sustainable Business Model of Elektro Ljubljana

The critical significance of the distribution network in the green transition will be demonstrated through the ability to integrate as many renewable energy sources (RESs) as possible into the network, a prerequisite for green growth. This involves 1.4 to 2 GW of power integrated only into the Elektra Ljubljana network, which is two to three times the current final load of the network, but in the opposite direction.

The first step in this direction is understanding and controlling the network entirely. A significant achievement in this area is the digitalisation of the system with the new advanced distribution management (ADMS) system, which allows real-time insight into the actual events in the network [50]. They have digitalised almost 17,000 km of the network in a full three-phase model, boasting high competitiveness among European distribution companies. Professionally, this is the observability or awareness of the system. The next step on this path is controllability. The system will have to adapt in real-time to significant load fluctuations due to the production of RESs, which significantly means increasing the scope of remotely controllable elements in the network, for which specific research and pilot projects are already underway. Dynamic tariffs are already being tested through development projects, and the first flexibility market in this part of Europe has been established. This flexibility approach should be vital in connecting unstable production and reliable supply in the green transition. In 2022, the entire mechanism is expected to be available to all our users with smart measuring devices. The company also put a lot of effort into simplifying and digitising user operations, but radical simplifications in this area will require the appropriate regulatory changes. In collaboration with conservation organisations, they are developing aboveground and underground network elements that are safe for birds and other wildlife. A new technical guideline has been adopted regarding protecting larger endangered birds (storks, owls, various birds of prey). The company also seeks to reduce greenhouse gas SF6 insulation use [51]. Finally, they contribute to sustainability goals through highly efficient system planning and operation, as electricity losses are shallow despite limited resources for the network, both at the European and global levels [52].

Lastly, Elektro Ljubljana ensures a safe and healthy working environment. They regularly monitor measures to reduce potential health risks, so smoking is prohibited at all locations [53]. The procedures for selecting new staff are thoughtful and geared towards the youth, focusing on values such as acquiring knowledge, continuous education, teamwork, and quality job performance. Existing staff must transfer knowledge and experience to inexperienced workers, thus developing and training a pool of experts in the long run [54]. Investing in employees' knowledge is the path to success. The company's goals include involving at least 75% of employees in education, thus providing an average of 20 h of training per employee. In 2021, 31 employees completed part-time education to obtain a higher degree in electrical engineering and energy [55].

In research and development projects, the company acquires knowledge and experience about technology. An essential part of the process is retrieving and conveying this knowledge to the employees. The company possesses the acquired knowledge through technical guidelines, instructions, procedures, and training courses and materials in the educational centre. Elektro Ljubljana has set goals for responsible and sustainable company operations aimed at a healthy and safe future for people and the environment. They operate systematically in the environmental management domain [56].

3. Materials and Methods

Factor analysis is a stable method used to identify and analyse hidden factors among a more significant number of variables. It is based on the assumption that observed variables can be grouped into a smaller number of variables or factors that explain a considerable amount of variability in the dataset. Factor analysis is employed to reduce the complexity of data and introduce new, less diverse variables that can still be analysed. In these methods, complexity often arises due to many variables, hence the principal component analysis (PCA) method, making the results more manageable.

Principal component analysis (PCA) is a multivariate method used to reduce data divisibility, uncover hidden patterns, and identify the main factors explaining data variability. PCA is based on the assumption that more minor variables can be represented by a closer relationship to the main components, which are a linear combination of the original variables. The principal components are tailored to increase the data variability they explain. The principal component with the highest variability explains the majority of the variability in the dataset, followed by identifying the next principal components that define the remaining variability in the emissions.

Principal component analysis is a statistical technique for transforming data with multiple variables into a smaller number of components (principal components) that capture the most significant variability in the data. This is a valuable method for simplifying data, identifying patterns, and reducing the dimensionality of data. The basic steps of principal component analysis include standardising the data with a mean of 0 and a standard deviation of 1. This is important because it allows for comparing variables with different units. Next, the covariance matrix is calculated, showing the correlations between all pairs of variables in the data. This is followed by calculating the eigenvectors and eigenvalues of the covariance matrix. Eigenvectors represent new variables that are linear combinations of the original variables, while eigenvalues measure the variability explained by each principal component. The principal components that capture the most significant variability in the data are then selected. The final step involves transforming the data using the chosen principal components. This creates new variables that are independent of each other and can simplify data analysis. Principal component analysis is often used to understand data structure, reduce dimensionality, visualize data, and identify major patterns in the data. It is also useful for addressing multicollinearity among variables in statistical analysis.

We used the method of linear regression analysis, which is a statistical technique used to study the relationship between dependent and independent variables. This method finds broad applications in various fields such as economics, social sciences, engineering, biology, medicine, and other scientific disciplines, as well as in the business environment. The fundamental components of linear regression analysis include productivity, which is the dependent variable (Y), examining the impact of the number of training hours on employee productivity. For independent variables (X), the number of training hours is an example. Both variables exhibit a linear relationship, meaning that a change in the dependent variable occurs in proportion to changes in the independent variables. This is typically expressed through a linear regression equation, such as $Y = aX + b$, where 'a' and 'b' are adjusted to the data. The goal of linear regression analysis is to estimate the parameter values (like 'a' and 'b' mentioned above) that best describe the relationship between variables. This is typically carried out using statistical techniques, such as the least squares method, which measures the proportion of variability in the dependent variable and explains it with the independent variables.

The dataset from 2002 to 2021 has been employed in the research. The data are obtained from the Yearly book of Elektro Ljubljana for microdata and the Statistical Office of the Republic of Slovenia (SURS) for macro data. During the research, we encountered a limitation regarding missing data for solar power production, as the company did not consistently produce them during the captured period from 2002 to 2021. A dummy variable was introduced for this variable. The data description is presented in Table 1, accompanied by communalities from the PCA analysis.

Success in the context of the mentioned variables can be described as generally accepted guidelines and principles for evaluating knowledge success within various companies and organisations. Specific references are not necessarily required, as these statements are general and stem from business principles and management principles applied in numerous organisations. Variables that are important for assessing a company's success in the energy sector can vary for each organization based on their specific strategy, market conditions, and goals. However, in general, an increase in these variables would indicate success in the knowledge of employees at Elektro Ljubljana. Higher GDP and GDP per capita can signify increased demand for electrical energy and more business opportunities, especially in the increased use of renewable energy sources, particularly solar energy. This, in turn, reflects success in knowledge related to the utilization and development of renewable technologies. Improving energy efficiency contributes to cost reduction and increased profitability, thereby indicating success in knowledge related to energy process management. Additionally, a decrease in household electricity consumption demonstrates that employees are successful in promoting energy efficiency, ensuring stable domestic primary energy supply, which is crucial for the successful operation of the company. Investments in research, development, and the number of researchers associated with electrical energy demonstrate the development of new capabilities and technologies resulting from successful planning and knowledge. Variables such as the number of employees based on their education and the number of educational programmes at Elektro Ljubljana are vital for the development of their knowledge and competencies, contributing to the company's success, as evidenced by variables such as Nominal Labour Productivity per Employee, the capital of the company Elektro Ljubljana, net business profit, EBIT–operating profit, and so on.

Table 1. Communalities.

Variable Name	Initialisation	Extraction
Gross Domestic Product	1.00	0.977
Gross Domestic Product per Capita	1.00	0.970
Consumer Price Index	1.00	0.278
Household Electricity Consumption	1.00	0.878
Renewable Sources and Waste	1.00	0.616
Electricity Production	1.00	0.209
Solar Power Production	1.00	0.806
Energy Efficiency	1.00	0.507
Domestic Supply of Total Primary Energy (TOE)	1.00	0.122
Gross Investments in Electricity (million EUR)	1.00	0.756
Research and Development Funds (1000 EUR)	1.00	0.819
Number of Researchers	1.00	0.952
Population	1.00	0.970
Nominal Labour Productivity per Employee	1.00	0.470
Distributed Electric Energy	1.00	0.660
Capital of the Company Elektro	1.00	0.960
Net Business Profit	1.00	0.856
Net Sales Revenue	1.00	0.844
Added Value (Fuzzy Yield)	1.00	0.976
Investment Expenditure	1.00	0.459
Share Value	1.00	0.957
EBIT–Operating Profit	1.00	0.910
Number of Employees at Elektro Ljubljana	1.00	0.850
Number of Users	1.00	0.636
Employees with Doctor's/Master's Education %	1.00	0.752
Employees with Higher Education %	1.00	0.959
Employees with Secondary Education %	1.00	0.943
Employees with Elementary Education %	1.00	0.827
Number of Participants in Education at Elektro	1.00	0.303
Number of Education Hours at Elektro	1.00	0.680

The initial analysis results reveal that most of the variables significantly impact the PCA analysis. However, two variables, namely 'Electricity Production' and 'Number of Participants in Education at Elektro', exhibit a different level of significance compared to the other variables. Despite this, we cannot disregard their importance in our research. As a result, we will conduct a more in-depth examination of these variables to gain a better understanding of their influence on the analysis. This approach is aimed at enhancing the accuracy of our findings and deriving meaningful conclusions. Consequently, we plan to include an extended review before presenting the results section. The theoretical framework has guided the selection of variables that contribute to the success of knowledge acquisition. These identified variables are considered pivotal factors in achieving knowledge success.

In summary, the overarching research question is as follows: What impact do knowledge and innovation variables have on the nominal productivity of an employee? The variable 'nominal labour productivity per employee' is calculated by dividing GDP at current prices by the number of employees. The hypothesis derived from this is that the number of training hours at Elektro Ljubljana positively influences the nominal productivity per individual employee.

In the context of factor analysis or principal component analysis (PCA), communalities represent the proportion of variance in each variable explained by the extracted factors. These values indicate how effectively the factors capture the original variables' variability. Within our dataset, the 'Variable Name' column lists the names of the analysed variables, the 'Initialisation' column reflects communalities before factor extraction, signifying the extent to which common factors explain each variable's variance. The 'Extraction' column, on the other hand, illustrates communalities after factor extraction, revealing the residual variance in each variable after accounting for common factors. To illustrate, let us consider

'Gross Domestic Product'—initially, it had a communality of 1.00, indicating full explanation by common factors. After factor extraction, 'Gross Domestic Product' shows a communality of 0.977, suggesting that approximately 97.7% of its variance can be attributed to common factors. Higher communalities post-extraction indicate the effective explanatory power of the selected factors in understanding the data's variability.

4. Results

In the following section, we present the results from the empirical part, where a quantitative analysis was conducted to study various internal factors of Elektro Ljubljana with various macroeconomic aggregates of the Republic of Slovenia. We calculated the chain index based on secondary data, which forms the basis for calculating the base indices to deflate the data. We combined the data and introduced them into the Statistical Package for the Social Science (SPSS Statistics 29) software, with which we conducted a factor analysis and the method of principal components. Thus, from a set of 30 variables, we obtained a smaller number of variables that show a strong interdependence or explained variance. The number of new variables from the Table 2 is three.

Table 2. Total variance explained.

Variable	Initial Eigenvalues			Extracted Sums of Squares of Factor Correlation	
	Total	**%Variance**	**Aggregate Data %**	**Total**	**%Variance**
Gross Domestic Product	15.972	53.241	53.24	15.972	53.241
Gross Domestic Product per Capita	3.493	11.643	64.88	3.493	11.643
Consumer Price Index	2.766	9.219	74.1	2.766	9.219
Household Electricity Consumption	19.78	6.594	80.7		
Renewable Sources and Waste	12.91	4.303	85		
Electricity Production	0.94	3.132	88.13		
Solar Power Production	0.816	2.719	90.85		
Energy Efficiency	597	1.989	92.84		
Domestic Supply of Total Primary Energy (TOE)	532	1.773	94.61		
Gross Investments in Electricity (million EUR)	0.439	1.464	96.08		
Research and Development Funds (1000 EUR)	0.34	1.133	97.21		
Number of Researchers	0.279	0.928	98.14		
Population	0.716	0.586	98.72		
Nominal labour Productivity per Employee	0.13	0.433	99.16		
Distributed Electric Energy	103	0.36	99.52		
Capital of the Company Elektro	0.074	0.248	99.77		
Net Business Profit	0.049	0.162	99.93		
Net Sales Revenue	0.12	0.39	99.97		
Added Value (Fuzzy Yield)	0.01	0.33	100		
Investment Expenditure	7.82×10^{-16}	2.61×10^{-15}	100		
Share Value	6.31×10^{-16}	2.10×10^{-15}	100		
EBIT–Operating Profit	4.72×10^{-16}	1.59×10^{-15}	100		
Number of Employees at Elektro Ljubljana	3.53×10^{-17}	2.12×10^{-15}	100		
Number of Users	3.08×10^{-17}	1.03×10^{-15}	100		
Employee with Doctor's/Master's Education %	-5.40×10^{-17}	-1.80×10^{-16}	100		
Employees with Higher Education %	2.17×10^{-17}	-7.22×10^{-16}	100		
Employees with Secondary Education %	-2.93×10^{-18}	-9.76×10^{-13}	100		
Employees with Elementary Education %	-4.94×10^{-13}	-1.65×10^{-15}	100		
Number of Participants in Education at Elektro	-8.07×10^{-15}	-8.04×10^{-16}	100		
Number of Education Hours at Elektro	-1.04×10^{-15}	-1.04×10^{-14}	100		

Data analysis is a crucial process in many fields, and it involves examining and interpreting large amounts of data to extract meaningful insights. One of the critical challenges of data analysis is understanding the relationships between different variables and factors in a dataset. Visualisations such as plots can help address this challenge because they provide a way to represent complex data relationships in a more intuitive and accessible manner. In a factor analysis plot, variables are grouped into different factors based on their correlation and interdependence. By examining these plots, researchers and users can quickly identify the critical relationships between variables and factors, facilitating a deeper understanding of the dataset. However, it is essential to note that these plots can be complex and challenging to interpret, especially when dealing with large datasets.

During our analysis we encountered an issue with the factor analysis plot, which broke at point 3. To address this issue, we focused our further research on only three components: (1) Added Value for Researchers and Users, (2) Investments in Electrical Energy, and (3) Allocated Funds for Education, Research, and Development, where AI could also be included in coming years. Using the component matrix (Table 3) to name these components, we gained valuable insights into our dataset and better understood the relationships between these components.

Table 3. Component Matrix.

Variable Name (Base Index)	1	2	3
Gross Domestic Product	0.966	−0.640	0.199
Gross Domestic Product per Capita	0.959	−0.080	0.212
Consumer Price Index	−0.255	−0.391	0.245
Household Electricity Consumption	0.898	−0.044	0.263
Renewable Sources and Waste	0.496	0.596	0.122
Electricity Production	−0.006	0.435	0.140
Solar Power Production	0.836	0.304	−0.119
Energy Efficiency	0.503	−0.502	0.430
Domestic Supply of Total Primary Energy (TOE)	0.056	0.288	0.188
Gross Investments in Electricity (million EUR)	0.450	0.728	0.156
Research and Development Funds (1000 EUR)	0.590	0.288	0.623
Number of Researchers	0.973	0.067	0.060
Population	0.972	0.136	0.083
Nominal Labour Productivity per Employee	−0.533	−0.062	0.427
Distributed Electric Energy	0.745	0.146	0.290
Capital of the Company Elektro	0.926	−0.315	0.057
Net Business Profit	0.695	−0.513	−0.332
Net Sales Revenue	−0.204	0.701	−0.557
Added Value (Fuzzy Yield)	0.954	0.009	–0.257
Investment Expenditure	0.250	0.068	0.626
Share Value	0.923	−0.316	0.063
EBIT–Operating Profit	0.725	−0.418	−0.457
Number of Employees at Elektro Ljubljana	0.676	0.614	0.125
Number of Users	0.982	0.058	−0.034
Employees with Doctor’s/Master’s Education %	0.758	0.302	0.294
Employees with Higher Education %	0.943	0.159	−0.209
Employees with Secondary Education %	−0.931	−0.238	0.142
Employees with Elementary Education %	−0.904	−0.065	0.710
Number of Participants in Education at Elektro	0.488	−0.060	0.247
Number of Education Hours at Elektro	−0.476	−0.042	0.627

In Table 2, we provide an explanation of the overall explained variability for each variable in the analysis. This table includes various statistical data, such as initial eigenvalues and computed sums of squares of factor correlations, which are employed to assess the variability explained by extracted factors. In the ‘Skupni % Variabilnosti’ column, we present the percentage of the total variability contributed by each variable, as determined by its initial eigenvalue. This percentage represents how much of the total variability in the data is independently explained by each variable.

The ‘Total % Agregata’ column illustrates the cumulative percentage of explained variability obtained by sequentially adding each variable in the listed order. The computed values of factor correlation squares reveal the sums of squares of factor correlations for each variable after factor extraction. These values indicate the portion of variability in each variable that can be attributed to common factors.

For instance, consider the variable 'Bruto domači proizvod'. Initially, it possesses an eigenvalue of 15.972, signifying that it independently explains a substantial portion of the dataset's variability, contributing to 53.241% of the total variability. Even after factor extraction, this variable retains an eigenvalue of 15.972, indicating that it continues to explain a significant portion of the data's variability.

This table provides a comprehensive understanding of how each variable contributes to the overall variability in the analysis, both before and after factor extraction, facilitating the assessment of their relative importance in comprehending the dataset.

Table 3 presents a component matrix that illustrates how various variables are associated with the extracted components in the analysis. This matrix displays values representing the relationship between each variable (specified in the 'Variable Name' column) and three extracted components (labelled as '1', '2', and '3').

For instance, Gross Domestic Product has a high positive value (0.966) in the first component (1) and a negative value (−0.640) in the second component (2). This indicates that this variable makes a significant contribution to the first component and has a negative impact on the second component. Similarly, Energy Efficiency has a high positive value (0.503) in the first component (1) and a negative value (−0.502) in the second component (2). This implies that this variable substantially contributes to the first component and has an opposing influence on the second component. Number of Employees at Elektro Ljubljana has a high positive value (0.676) in the first component (1) and also a high positive value (0.614) in the second component (2). This indicates that this variable positively contributes to both components. In essence, the component matrix provides insights into how each variable contributes to specific components, with positive and negative values indicating whether the variable positively or negatively influences a particular component. This is crucial for understanding how variables are interrelated and how they contribute to explaining variability in the analysis.

The component matrix is used to explain income factors by extraction. It shows how the weights of individual factors are associated and how individual variables can be interpreted in the context of factors. The component matrix is helpful for identifying the most important variables for all factors. The larger the loadings, the stronger the correlation between factors and variables. When they are positive, it means a positive correlation, and when negative, a negative correlation. This matrix makes it possible to understand how variables influence each other. Investments by electric companies in employee education and energy-related assets positively impact GDP. This consequently increases employee productivity, contributing to the sustainable development of society.

The variable 'Nominal Labour Productivity per Employee' (NLPE) is derived as the quotient of GDP at current prices and the number of employees defined by Sollow. This variable is regarded as a dependent variable in the regression analysis, subject to the stated hypothesis. To some extent, it shows how much of the total economic activity in nominal prices in a given period can be attributed to each employee.

Overall, factor analysis can be a handy tool for data analysis. However, it is essential to use it with other analytical techniques and be aware of their limitations and potential issues. By doing so, we can fully leverage the power of data by regression analysis to gain insights and make informed decisions:

$$y_t = 53.27 - 0.53 \cdot \text{K1} - 0.06 \cdot \text{K2} + 0.43 \cdot \text{K3} + \varepsilon_t, \tag{1}$$

where PCA-defined latent factors K1, K2, and K3 have statistically insignificant coefficients except for K1 at the 1% level. In the regression model y_t explains the NLPE dependent variable.

One can conclude that the number of hours of training at Elektro Ljubljana (marked violet in Table 3) could positively affect the nominal productivity per employee in Slovenia (marked green in Table 3). Therefore, the answer to the research question 'What influence do knowledge and innovation variables have on the nominal productivity of an employee?' is that the influence is significant and correlated but could have a greater extent. In contrast, technological training and knowledge in the future training could have an even higher impact.

On top of that, the derived hypothesis that the number of hours of training in the company Elektro Ljubljana has a positive effect on nominal productivity per individual employee in Slovenia is partially confirmed. This claim was supported by the econometric method of linear regression analysis, where the dependent variable is the nominal productivity per employee in Slovenia. The deterministic coefficient result shows that 47% of the K1 impacts the dependent variable NLPE, which is satisfactory for further consideration. The main econometric results from the equation 1 are as follows. The result in the Beta column of the standardised coefficient represents the regression coefficient, which measures the change in the dependent variable for a one-unit change in the independent variable. Statistically significant is the first factor, the Added Value of Researchers and users (K1), as it shows lower values than 0.05, but not the Funds Allocated to Education, Research (K3) and Development and Investments in Electrical Energy (K2), as the statistical significance is higher than 0.32.

Overall, based on the results of econometrics, the hypothesis that the number of hours of training in the company Elektro Ljubljana positively affects nominal productivity per individual employee is partially confirmed, while K1 is statistically significant. Still, on the contrary, K3 is insignificant, which indicates that there is a path to extend the training in the company Elektro Ljubljana, and we can for sure say that this could be with the support of machine learning and other technological improvements or innovations.

We confirmed the hypothesis using the econometric method of linear regression analysis (Table 4), where the dependent variable is nominal productivity per employee in Slovenia. The hypothesis was confirmed based on the following results. The R-squared value shows that 47 percent of the variation is explained in the dependent variable, which is satisfactory for our analysis.

Table 4. Regression model table.

Model	Unstandardized Coefficient		Standardized Coefficient	
	B	**Std. Error**	**Beta**	**t**
1 (Constant)	53.273	6.395		8.331
REGR factor score 1 for analysis 1	−19.230	6.561	−0.533	−2.931
REGR factor score 2 for analysis 1	−2.229	6.561	−0.062	−0.340
REGR factor score 3 for analysis 1	15.381	6.561	0.427	2.344

The result in the Beta column represents the regression coefficient, which measures the change in the dependent variable for a one-unit change in the independent variable. Statistically significant are the values of Added Value by Researchers and Users (factor 1) and resources allocated to education, research, and development since they show values lower than 0.05.

Based on the results, we confirm the hypothesis that a higher number of hours of education in the company Elektro Ljubljana, allocated to research and development, positively impacts the nominal productivity per employee in Slovenia.

Sensitivity analysis allowed us to examine the credibility of the study, investigating how changes in input data affect the output results. In our case, the input data was the base index of the number of hours of education, as it can demonstrate a higher level of knowledge, while the output result compares the base index of GDP per capita. We assumed that the value of the BASE INDEX ST.UR_IZOB would change by 5% upwards and 5% downwards, while the base indices of GDP per capita remained unchanged (Table 5).

Table 5. Variables in base indices.

	2021	2020	2019 2018
Education hours + 5%	1.76%	2.65%	2.29% 2.26%
Education hours − 5%	1.78%	2.62%	2.25% 2.22%

5. Discussion

Knowledge within a company is crucial for successful operations. Companies with employees with a broad knowledge and skill range are more competitive and adaptable. It is essential for successful operations that a company provides an appropriate range of training for its employees and shares knowledge within the company. Collaboration and information exchange can contribute to process improvement and better problem-solving. In today's world, where technology and business processes rapidly evolve, companies must stay current with modern industry trends and developments. Knowledge sharing among employees and continuous education are key factors that can help a company succeed in its growth. Effective intellectual capital management helps companies enhance competitiveness, innovation, and efficiency. Knowledge management is thus part of the entire process in business operations and company management. Its importance is reflected in productivity, leadership, employee collaboration, customer satisfaction, etc.

With the findings from the theoretical and empirical parts of the research, we can answer the posed research questions and the purpose of the research task. A good manager who motivates employees through education and investment in innovation increases efficiency and productivity within the company. A company's success, measured by various indicators we used in the variables of the research task, positively influences macroeconomic factors. The research was conducted using quantitative analysis based on the factor method. Among all communalities, we selected those with a high determination coefficient. During the research, we encountered a limitation regarding missing data for solar power production, as the company did not consistently produce them during the captured period from 2002 to 2021. A dummy variable was introduced for this variable.

Exploring this topic contributes to developing the importance of education and innovation towards sustainable development. Elektro Ljubljana's vision is based on the planet's future and life on it. Energy will play a crucial role in this vision. It believes in renewable energy sources and a low-carbon society, through which they will ensure a green, sustainable future where our descendants can lead better lives accompanied by machines and robots. It is crucial to share knowledge, especially with electricity consumers and employees, who can actively participate in green transformation by adjusting consumption and using their energy sources.

This is why investing in human knowledge is essential so that individuals can utilise their knowledge to the best of their ability, develop their talents, and contribute to the overall success of society. Various researchers [57–59] state that the knowledge of those engaged in creative work is essential for personal and organisational development. Employees with specialised knowledge, especially in economics, are imperative human resources for an organisation and desired community members. The more excellent and higher the quality of their knowledge, the better the results achieved through collective action. The paper's authors [60] present a theoretical model that examines the factors influencing AI–human partnerships and their impact on business performance. They analysed data obtained from employees in the UK's creative industries and identified key strategies to enhance collaborative intelligence capabilities.

Moreover, the authors of the recent study [61] found that students were trained in creativity and AI for 8 weeks, after which interviews were conducted to understand how they perceive AI and creativity. Four key concepts emerged: social, affective, technological, and learning factors. Students with a better knowledge of AI were positive, while those with less knowledge were fearful. Most students believe that AI cannot match human creativity.

Change is the only certainty in today's modern, knowledge-based society and economy. A company or manager who detects them quickly and takes appropriate action will be more successful. Employing the right experts in the correct positions is also critical to achieving goals. The presented set of indicators, together with the optimisation methods and models used, machine learning tools, or methods of artificial neural networks, significantly contributes to preliminary analyses of the transition to sustainable energy sources and simultaneous sustainable energy management. It is the foundation for a comprehensive discussion among policymakers and decision-makers, researchers, industry representatives, civil society, and other stakeholders, and for introducing innovations in the sustainable energy transition process.

Renewable energy sources (wind, solar, hydro energy, ocean energy, geothermal energy, biomass, and biofuels) are an alternative to fossil fuels and help reduce greenhouse gas emissions. In the last 15 years, EU legislation promoting such energy sources has developed significantly.

For further research, we propose that additional variables for European companies and countries be included in the quantitative analysis, like Granger Causality and panels. Given the leadership in electricity production for all new technologies, not only AI, we suggest Denmark be included, as in 2021 it produced 61% of its electricity from renewable sources, primarily wind turbines [62,63]. In addition to electricity production from renewable sources, Denmark actively promotes sustainable development in other areas, such as green architecture, sustainable transport, and efficient energy use in buildings [64].

6. Conclusions

In conclusion, this comprehensive study has provided valuable insights into the relationship between knowledge and innovation variables and Slovenia's nominal productivity per employee, focusing on the impact of training at Elektro Ljubljana. The analysis has revealed several key findings and implications. Firstly, our research indicates that the number of hours of training at Elektro Ljubljana can positively influence the nominal productivity per employee. This suggests that investing in employee training and knowledge development is a promising strategy for enhancing productivity within the company and, by extension, contributing to broader macroeconomic factors. However, it is essential to note that this influence is significant but could be further optimised. The econometric analysis, particularly the linear regression model, has provided statistical support for the hypothesis, with the deterministic coefficient showing that 47% of the variance in Nominal Labour Productivity per Employee (NLPE) can be attributed to the Added Value of Researchers and Users (K1). This result underscores the significance of this factor in the context of our study. Conversely, factors such as funds allocated to education, research (K3), development, and investments in Electrical Energy (K2) were found to be statistically insignificant in their influence on nominal productivity. This suggests that there may be room for extending training initiatives within Elektro Ljubljana, particularly in conjunction with machine learning and technological innovations, to enhance their impact on productivity further.

Overall, our research highlights the critical role of knowledge and innovation in a company's success and its ability to adapt and remain competitive. Effective knowledge management, collaborative learning, and investment in innovation play pivotal roles in enhancing productivity, efficiency, and overall competitiveness. In a rapidly evolving business landscape, staying current with industry trends and fostering a culture of continuous learning and knowledge sharing is imperative. Furthermore, the study offers valuable insights into the importance of knowledge in sustainable development, specifically within the context of Elektro Ljubljana's vision for a green and low-carbon future. Knowledge sharing among employees and investing in human knowledge are essential for organisational success and contributing to a sustainable, green transformation of society and the energy sector. This research has broader implications for transitioning to sustainable energy sources and optimising sustainable energy management. As renewable energy sources gain prominence in the EU, the methods and models presented in this study, including machine learning tools and artificial neural networks, provide a foundation for in-depth discussions among various stakeholders and the introduction of innovative approaches to sustainable energy transitions.

To extend the scope of future research, we recommend the inclusion of additional variables related to European companies and countries, employing Granger Causality and panel analysis. Additionally, exploring Denmark's leadership in renewable energy production and sustainable development practices could offer valuable insights for further studies.

In conclusion, this research underscores the critical role of knowledge, training, and innovation in enhancing productivity and contributing to broader sustainability and economic goals. It provides a robust foundation for further exploration and policy development in the ever-evolving landscape of knowledge-based economies and sustainable energy transitions. The findings of this study carry significant policy and managerial implications. From a policy perspective, governments and regulatory bodies should consider incentivising and supporting employee training programmes, particularly in industries with potential productivity gains, such as the electrical energy sector. Additionally, organisations must promote knowledge sharing and innovation to boost productivity and competitiveness. Managers within companies, on the other hand, should recognise the value of investing in their employees' knowledge and skills and should actively foster a culture of continuous learning and collaboration. Furthermore, they should explore opportunities to integrate machine learning and other technological advancements into their training initiatives. Lastly, emphasising sustainable energy development and adopting renewable energy sources necessitates a collaborative effort between the public and private sectors to drive innovation and transition towards a greener, low-carbon future [65].

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