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IMPACT OF NEW TECHNOLOGIES ON TOTAL FACTOR PRODUCTIVITY IN THE CONTEXT OF INDUSTRY 4.0

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Purpose: Reducing the execution time of individual processes, or the execution of work by robots and cobots, affects the number of labor hours in the enterprise in production. The efficiency of the use of resources in production can be measured by the partial productivity index. Therefore, it was decided to address the topic of the impact of new technologies on productivity.
Methodology: Analysis of international literature from main databases and Polish literature, critical analysis of the literature, and analysis of macroeconomic statistical data focused on gross domestic product, employment, and innovation activities of enterprises. Data for analysis are from OECD statistical databases and the Poland Central Statistical Office.
Findings: An analysis of the literature on productivity and the impact of new technologies on its level showed that the most obvious is to study labor productivity. Some studies for national economies have shown just such a relationship. Taking this into account, the author of the publication undertook an analysis of the situation in Poland. A significant increase in innovation-active enterprises (especially in services) and a significant increase in the share of R&D spending were seen. The share of spending on innovation and new technologies is growing, with a steady increase in the productivity of the economy. Based on this, the conclusion is that investment especially in new technologies can help improve productivity levels.
Research limitations: The analysis mainly concerns the research desk, the analysis of data for the Polish economy is based on data available in the databases of the Central Statistical Office and the OECD. Continued research on enterprises is advisable to be able to better study the productivity of enterprises.
Originality/value: Economy and statistic analysis of subjects related to the impact of new technology on productivity using analysis of indicators for the Polish economy.
Keywords: productivity, total factor productivity, new technologies, research and development.
Category of the paper: general review, research paper.

1. Introduction

With the development of Industry 4.0, it is becoming increasingly common for manufacturing companies to digitalize and use new technologies to implement processes. The COVID-19 pandemic has gone some way to accelerating the implementation of new solutions (Dębkowska et al., 2020). The use of automation and robotization contributes to reducing the employment of human labor in process execution. A good example was presented in the papers (Grencikova et al., 2020; Yang et al., 2023). The employment or number of working hours is a component of the measure of labor productivity (Ergül, Göksel, 2020). Reducing the execution time of individual processes, or the execution of work by robots and cobots, affects the number of labor hours in the enterprise in production. On the other hand, processes are being automated and robotized, which requires capital investment. The efficiency of the use of capital in production can be measured by the capital productivity index. Therefore, it was decided to address the topic of the impact of new technologies on productivity.

The purpose of this article is to analyze the literature on productivity and the impact of new technologies on it. Taking into account that the COVID-19 pandemic contributed to the increased number of innovations implemented in manufacturing companies. Statistics for Poland related to productivity and new technologies were analyzed to find an answer to the research question: does the development of new technologies affect productivity?

A critical analysis of the literature, literature review, and analysis of macroeconomic statistical data and inference based on this will verify whether innovation is important in achieving productivity improvements. It was decided to analyze data for the 10 years from 2013 to 2022. Analysis of macroeconomic statistical data focused on gross domestic product, employment, and innovation activities of enterprises. Data for analysis are from OECD statistical databases and the Poland Central Statistical Office.

2. Productivity and new technology in manufacturing companies

The literature presents productivity as a complex issue, analyzed on many levels. Both at the micro-scale in enterprises and globally for the national economy. Productivity growth is equated with increased prosperity in the economy (Piętowska-Laska, 2019). Klaus Schwab writes (Schwab, 2016) that productivity is measured as labor productivity or an indicator of total productivity, slows down in the decade preceding the survey. This was noted despite a sharp acceleration in technological advances and investment in innovation (The Conference Board, 2015).

Contemporary determination of productivity is manifested in the dual approach to the term productivity, namely (Piętowska-Laska, 2019):

- economic and social, i.e. focusing the way of thinking on a constant search for ways to improve the current state of the system,
- technical, which is a measure of the efficiency of the system.

Productivity is a relationship between the goods and services produced in a certain period, and the resources consumed to produce them in that period (Christopher, 1985). It measures how efficiently production inputs are being used in an economy to produce a given level of output (OECD, 2021). Measuring productivity is simple when a single output is produced with a single input. A little bit complicated calculations are when we have multiple inputs (Coelli et al., 2005). In this case, productivity can be calculated as partial ratios (Kosieradzka, 2012; Rostek, Knosala, 2018). General productivity is divided due to labor and capital (A Guide to Productivity Measurement, 2011; Measuring Productivity - OECD Manual, 2001), as well as materials and energy (Hannula, 2002; Prokopenko & North, 1996). These are the most common divisions. In companies also exist situations that are more than one output. In that case, total factor productivity (TFP) may be defined as a ratio of aggregate output produced relative to aggregate input used (Coelli et al., 2005).

We can distinguish the new technologies that improve the implemented processes in enterprises. The development of companies through the use of new technologies is one of the factors of competitiveness. The Industrial Revolution – Industry 4.0 (Schwab, 2016) has initiated changes in companies towards the use of artificial intelligence and digitalization (Davies, 2015). Based on definitions of productivity, it is important to take into account that technology is one of the resources used in production. With the use of new technologies, the question is whether such investments bring tangible benefits to companies. One indicator of a company's efficiency is productivity (Sickles, Zelenyuk, 2019), i.e. the degree to which its resources are used. One measure of economic efficiency is total factor productivity. It was decided to analyze whether the total factor productivity is also changing due to the increased implementation of new technologies.

Productivity growth reflects the ability to produce more products by better combining inputs, through new ideas, technological breakthroughs and improved business models. They transform the production of goods and services, supporting economic growth and raising living standards and prosperity (OECD, 2024).

Before the COVID-19 crisis, much attention was paid to the long-term productivity slowdown observed in various countries. This was called the productivity paradox because the productivity slowdown occurred during a period of significant technological change. It is anticipated that the focus on productivity will return and become more important as the recovery from the COVID-19 crisis takes place (OECD, 2021).

The productivity of an economy is usually measured in two complementary ways. Firstly, as labor productivity, i.e. value added per unit of labor (e.g. one employee or hour worked). Second, total factor productivity (TFP) reflects the efficiency with which capital and labor resources are transformed into value-added. In economic terms, a higher TFP value is desirable, although its interpretation is not straightforward. A change in TFP is sometimes equated with the effect of technological innovation, but this approach is oversimplified (Ministerstwo Rozwoju i Technologii, 2022).

Labor productivity, measured as Gross Domestic Product (GDP) or Gross Value Added (GVA) per hour worked or per worker, is one of the most widely used measures of productivity. Labor productivity measures based on hours worked better capture the use of the labor input as compared with measures based on numbers of persons employed (head counts) due to cross-country differences in working time patterns (e.g. related to part-time employment) and employment legislations (e.g. statutory working time) (OECD, 2021).

Productivity is influenced in part by external factors, but there are several steps to improve productivity through innovation, adoption of new technologies, and management practices (Klaas de Vries, 2023; Penney, Pendrill, 2022). Robotics allows for greater efficiency in the manufacturing process and consequently greater labor productivity (Ballestar et al., 2020).

Industry 4.0 is an industrial revolution that relies heavily on technological developments including the digitization of processes carried out (Frank et al., 2019). The main pillars of the Industry 4.0 concept are (Erboz, 2017): big data, autonomous robots, simulation, additive manufacturing – 3D printing, (Industrial) Internet of Things, cloud computing, augmented reality, horizontal and vertical integration and cyber security. The same pillars were identified in the article (Rüßmann et al., 2015).

Manufacturing will be transformed from single automated cells to fully integrated, automated facilities that communicate with one another and boost flexibility, speed, productivity, and quality (Rüßmann et al., 2015). Industry 4.0 concept significantly affects labor productivity in individual countries i.e. (Grencikova et al., 2020). The empirical results of a study in the ASEAN region (countries Malaysia, Thailand, The Philippines, Vietnam, and Indonesia) show that there is a relationship between technological progress and labor productivity (Nasir et al., 2024).

Based on several papers containing the results of productivity studies (Bettiol et al., 2024; Črešnar et al., 2023; De La Fuente-Mella et al., 2019; Hubert Backhaus, Nadarajah, 2019; Rosin et al., 2020), it can be concluded that productivity improvements can be achieved by implementing new technologies, but also organizational changes.

Some research suggests that innovation in digital technology can increase total factor productivity (Aly, 2022; Wang, 2023; Zeng et al., 2023). Digitalization improves total factor productivity by reducing transaction costs, facilitating servitization, and stimulating innovation investment (Wen et al., 2022).

3. Total productivity factor in Poland

An analysis of the literature on productivity and the impact of new technologies on its level showed that the most obvious is to study labor productivity. Capital productivity can also change in the face of changes related to the implementation of new technologies in the enterprise. Some studies for national economies have shown just such a relationship. Taking this into account, the author of the publication undertook an analysis of the situation in Poland.

The first measure examined for the Polish economy was gross domestic product (GDP) from 2013-2022 in millions of US dollars. Figure 1 shows the values for Poland, the European Union (UE), and OECD countries. Each curve shows the gradual growth of the economies. For Poland, there was an 86% increase in GPD over the period under review, in the EU by 61%, and for the OECD by 53%. Using the OECD economies as an example, a slump in 2020 is evident. This coincides with the first year of the pandemic COVID-19 when many companies reduced or ceased operations. However, Poland has not seen a decline. In 2019 GPD amounted to 1347315.63 million USD and in 2020 it was 1376571.30 million USD. That is more than 2% growth when there was more than a 2% decline for the EU.

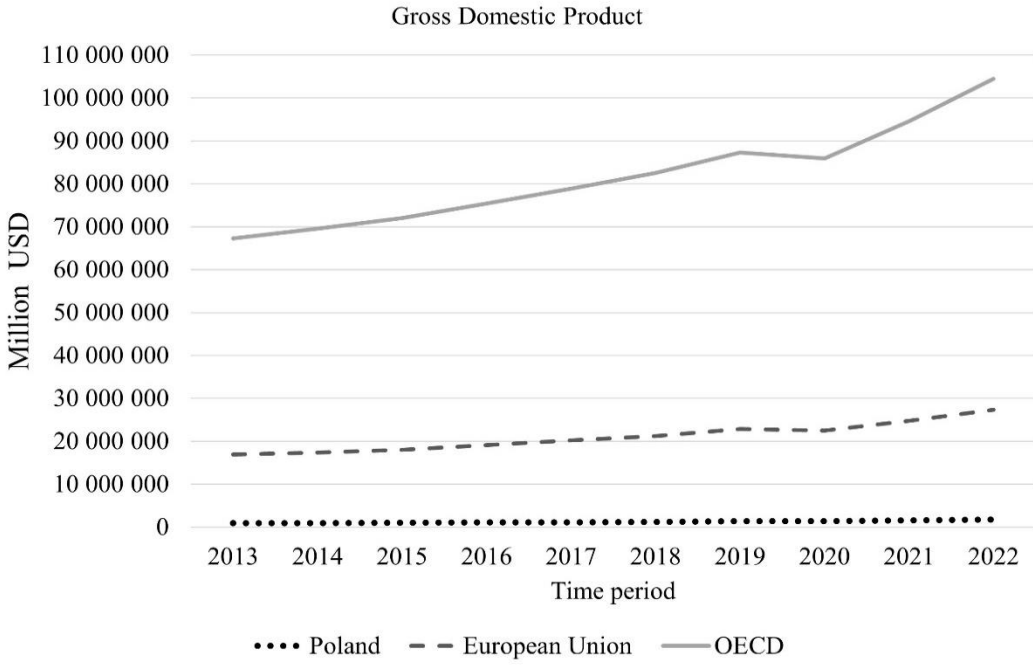

Figure 1. GDP in millions of US Dollars.

Source: Own elaboration based on (OECD Data Explore, 2024).

Statistics on gross domestic product per hour worked were further analyzed. Figure 2 shows the percentage change from the previous year. Analyzing the 10-year period for Poland, a decline is evident in 2020, when data for the EU and OECD countries showed an increase in the indicator. GDP per hour worked is one of the indicators of labor productivity. It is interesting to note that in subsequent years, Poland has seen higher labor productivity increases than the EU and OECD.

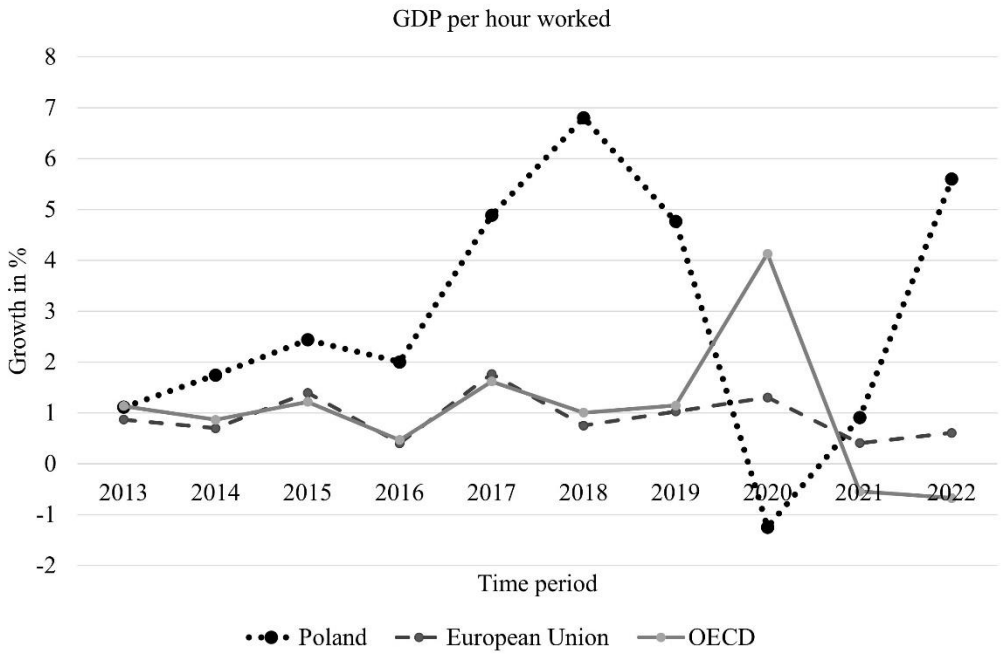

Figure 2. GDP per hour worked – growth rate in percent per annum.

Source: Own elaboration based on (OECD Data Explore, 2024).

Unit labor costs (ULC) measure the average cost of labor per unit of output. They are calculated as the ratio of total labor costs to real output. The percentage change in unit labor cost (Figure 3) compared to the previous year in Poland is similar to that for the EU. The trend of change is the same in 2013-2015 and Poland will see larger increases in ULC in subsequent years. This means that labor costs per unit of output are rising more in Poland than the EU average indicates.

Figure 3. ULC – growth rate in percent per annum.

Source: Own elaboration based on (OECD Data Explore, 2024).

The study of the impact of new technologies on productivity checked internal expenditures on research and development to GDP in Poland (Figure 4). During the period studied, data was collected for the years 2014-2022. Every year, the share of innovation in the gross national product is increasing. In 2013, less than 1% of GDP was spent on R&D, while in 2022 it was almost 1.5%. This is influenced by the percentage share of innovation-active enterprises relative to all enterprises (Figure 5). During this period, internal expenditures on research and development activities increased by almost 200%. From 16168 million PLN to 44702 million PLN in 2022. In 2020, there was an increase in the share of innovation-active enterprises in both industry and services. The following year brought a slowdown in growth, however, in 2022 active enterprises arrived. According to data from the Central Statistical Office (CSO) of Poland, in 2022 about 32% of total enterprises in industry and services qualified as innovative.

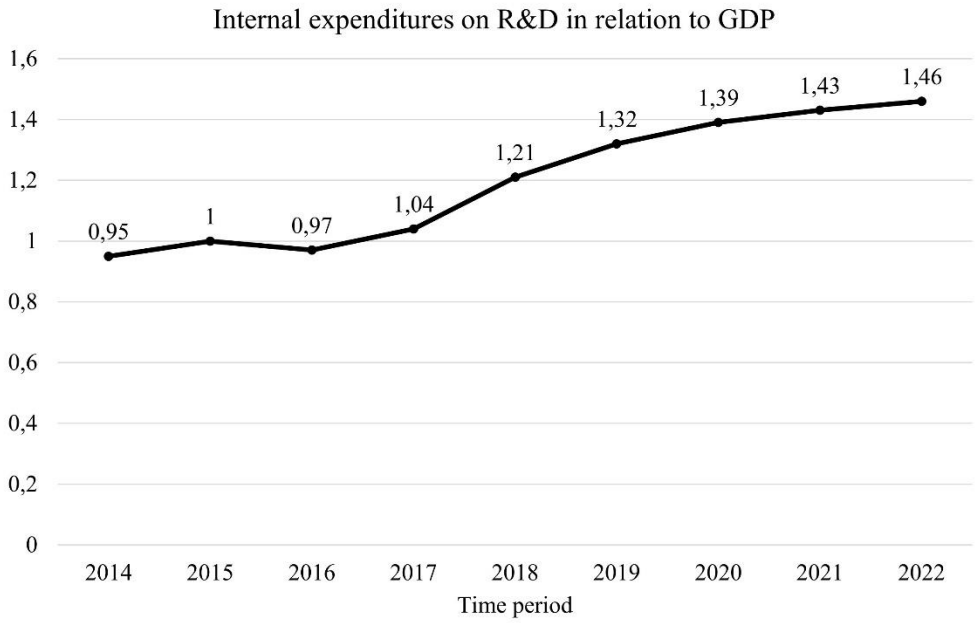

Figure 4. Internal expenditures on research and development in Poland to GDP.
Source: Own elaboration based on CSO Poland.

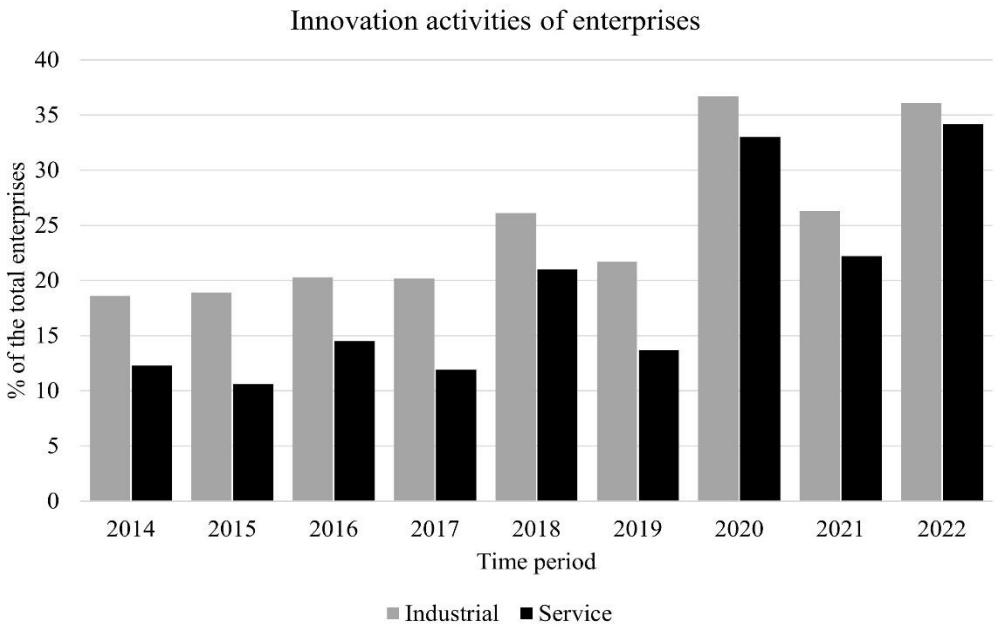

Figure 5. Innovation activities enterprises in Poland – percent of the total.

Source: Own elaboration based on CSO Poland.

The growth of innovative enterprises and their active innovation activities is causing R&D spending to increase. This also affects the increase in the unit cost of producing a product or service. At the same time, there is a decline in the growth of employee employment. In 2020, there was even a situation of downsizing (Figure 6). The same year just saw a decline in labor productivity (Figure 2). At the same time, there has been a significant increase in innovation-active enterprises.

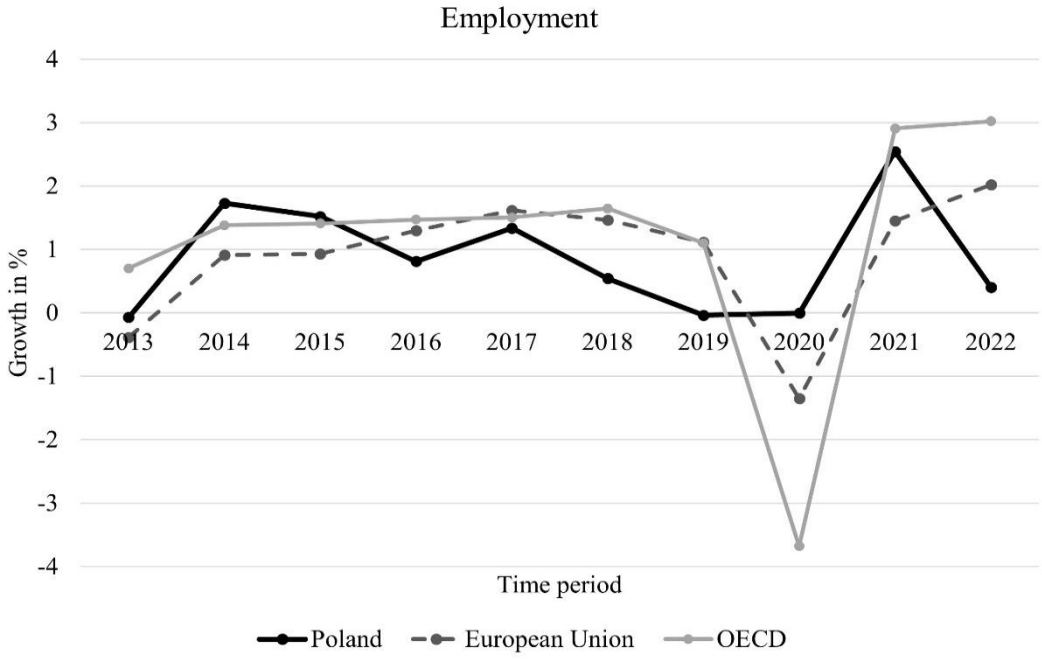

Figure 6. Changes of employment – growth rate in percent per annum.

Source: Own elaboration based on (OECD Data Explore, 2024).

Summary

The article reviews the literature on new technologies, productivity and the relationship between them. Based on a critical analysis of the literature, it was found that productivity at the level of the economy is measured primarily by employment and hours worked. The next section just analyzes employment, the level of innovation of enterprises, and investment in R&D using Poland as an example. It was observed that changes in employment with opposite changes in innovation activity of enterprises cause changes in the level of productivity of the economy measured by GDP per hour worked. Taking into account the statistics available from the Central Statistical Office Poland, investment expenditures as well as output sold collapsed in the same period. This is characteristic of the year 2020. This may indicate the relationship between investment, innovation in new technologies and employment, and the level of national productivity.

In 2018 there was the largest year-on-year increase in the productivity index, measured as GDP per hour worked. This year also saw a significant increase in innovation-active enterprises (especially in services) and a significant increase in the share of R&D spending. The share of spending on innovation and new technologies is growing, with a steady increase in the productivity of the economy. Based on this, the conclusion is that investment especially in new technologies can help improve productivity levels.

In an attempt to answer the question of whether new technologies have an impact on productivity, it was determined that there is a relationship. However, this requires more thorough research. Thus, the validity of studying the impact of new technologies on productivity was confirmed. Being aware of the implementation of the Industry 4.0 concept in enterprises, the next step will be a quantitative study of manufacturing enterprises.

The research conducted on the example of the Polish economy confirms the assumptions related to the increasing importance of new technologies in the level of productivity. The conducted analysis is a contribution to the theory related to productivity with the impact of new technologies. In practical terms, it shows that it is necessary to deepen the research by verifying the impact of new technologies on enterprises. In further research, an attempt will be made to verify productivity survey methods and a proposal to study the impact of new technologies on enterprise productivity.

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