International Journal of Scientific and Management Research
Volume 8 Issue 4 (April) 2025
ISSN: 2581-6888
Page: 128-136

Economic Impact of the Implementation of Robotic and Digital Technologies on Value Added in the Manufacturing Sector

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DOI - http://doi.org/10.37502/IJSMR.2025.8409

Abstract

This article examines the economic impact of the implementation of robotic and digital technologies in creating value in the manufacturing sector. It explains the function of innovations such as automation, artificial intelligence, the Internet of Things, and big data in augmenting productivity, product quality, and reducing costs. The research focuses on how the technologies contribute towards optimizing production activities, reducing operating costs, and increasing production flexibility. Successful use of robotics at large companies is analyzed. Technology implementation socio-economical outcomes, such as job creation, and workforce training, are studied as well.

Keywords: Robotics, Digitalization, Value added, Manufacturing sector, Automation.

1. Introduction

Over the past decades, there have been immense transformations in the world economy. One of the important reasons is the massive adoption of new technologies. The manufacturing sector, being the main component of the economy, is actively adapting to them, striving to improve its efficiency, product quality and competitiveness in world markets.

One of the significant determinants of the effectiveness of these efforts is value added, which represents the aggregate contribution to the production of the final output through the transformation of inputs into goods or services with enhanced economic and consumer value. The role of technology in its creation is especially important for the USA, where innovations of this kind are a crucial factor in increasing production efficiency. The purpose of this article is to investigate the impact of the implementation of robotic and digital technologies on increasing value added in the manufacturing sector.

2. Main part. Theoretical foundations of value added in the manufacturing sector

Value added is one of the most important economic indicators that quantifies the value received at each stage of the production of goods and services. In industry, it refers to the difference between the value of the output goods and resources cost used to make them, such as raw materials, material, energy, and labor (fig. 1).

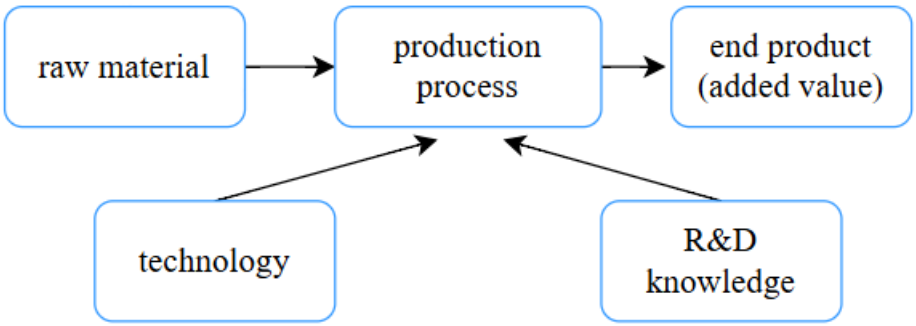

Fig. 1: The scheme of added value in the production process

The role of added value in the economy is multifaceted. It is the foundation of gross domestic product construction and serves as an important indicator in judging the competitiveness and stability of the national economy as well. This indicates the industry's ability to create value and make a profit in the production process. In addition, its development creates jobs, increases the productivity of the production process and increases tax revenues to the budget, thereby contributing to economic progress. However, in the industrial sector, this process depends on a number of factors, which can be categorized as shown in table 1.

Table 1: Factors affecting the increase of added value in industry [1, 2]

Category	The factor	Description
Technological	Introduction of innovative technologies	New technologies increase productivity and product quality.
	Using automation	Reduce costs, improve accuracy, and accelerate production processes.
	The use of artificial intelligence (AI) and big data	Improved process management and forecasting.
Organizational	Optimization of production processes	Reducing costs and improving quality through the reallocation of resources.
	Modernization of equipment	Increase the efficiency of resource use and improve technological processes.
Socio-economic	Professional development of the workforce	Increase productivity and quality of work through employee training.
	Improving working conditions	Increase employee motivation and reduce staff turnover.

Thus, value added is an important indicator of production efficiency, and its development is the result of a synergetic influence of techno-trends, organizational factors, and socio-economic changes. Advanced technology is a catalyst of this process, providing firms with enhanced productivity and higher product quality.

3. The impact of robotic technologies on the manufacturing sector

One of impactful technologies on the modern manufacturing sector, transforming its structure and processes, is robotization. It began to develop in the middle of the 20th century against the background of the intensive growth of industrialization and the need to increase productivity, when companies began to realize the importance of introducing automatic and semi-automatic

systems to perform routine tasks. Early on, robots were applied to only a few, very specific tasks, including packaging and simple assembly, primarily in the auto industry. One of the first to be developed was the Unimate industrial robot, which was installed at General Motors factories in 1961 and was designed to perform repetitive tasks [3].

Gradually, in the 1980, robots was a technological surge, and they began performing more advanced activities, like testing and quality control, with improvements in software. Automation also began to extend beyond the automobile industry around this period and entered other fields that required high accuracy and minimizing errors on the part of humans.

The modern period covers an increasingly wide range of operations and productions. Combination of AI, machine learning (ML), and robots with flexible production systems allows enterprises to respond to novel situations and enhance production flexibility more effectively. They no longer merely perform standard tasks, but also adjust their behavior according to their needs, making it easier for increased customization of production and lowered costs.

At an international scale, the market for the above technologies continues to grow. The latest available data state that in 2024 it was valued at 94,54 billion of USD, and in 2034, is valued at approximately 372,59 billion of USD with an average annual growth of 14,70% (fig. 2).

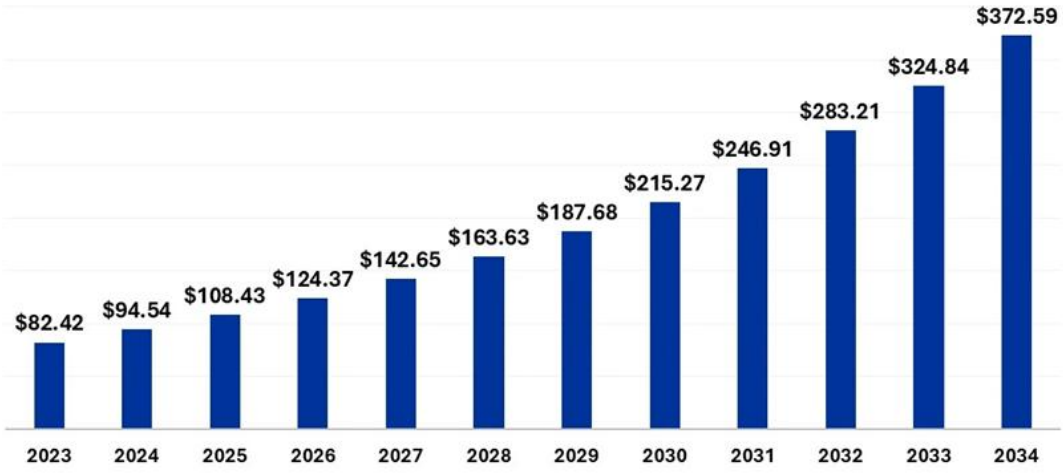

Fig. 2: Robotics market size, billion USD [4]

Robotization has several significant economic effects that directly influence value added. It makes productivity of labor rise to a large degree, since the robots do not require breaks and can work at high speed with accuracy. It leads to reducing the production cycles and, as a consequence, increasing the level of output. It is also linked with the improved quality of products. Robots perform repetitive tasks, which gives uniformity to the manufacturing process and removes defects and errors. This directly comes to reducing rework expenses and enhancing the company's reputation in the market.

It also contributes to a significant reduction in labor costs. The introduction of such systems allows enterprises to reduce the need for labor to perform repetitive tasks, which leads to a reduction in labor costs [5]. At the same time, reduced costs in terms of reprocessing defective products and transport also result in reducing overall expenses and improving business efficiency.

Successful examples of robot technologies' application are the proof of their economic and production advantages. Particularly, Tesla, putting them into its factories, significantly accelerated the manufacture of the cars, allowing the company to respond more quickly to trends in the market and reach volumes much greater [6].

Thus, their use in production has a multifaceted impact on the economy. It results in abrupt productivity growth, cost reduction, and product quality improvement. It also affects the labor market, forcing workers to adapt under new circumstances and form new spheres of professional activity linked with high technologies.

4. The role of digital technologies in increasing value added

In recent years, digitalization of production has been among the drivers of value added growth in the industry. Application of such technologies not only significantly improves production processes but also directly impacts the economy of businesses. The global market is demonstrating rapid growth. It is expected that by 2033, its size will reach approximately 8567,4 billion USD, compared to 829,5 billion USD in 2023 (fig. 3).

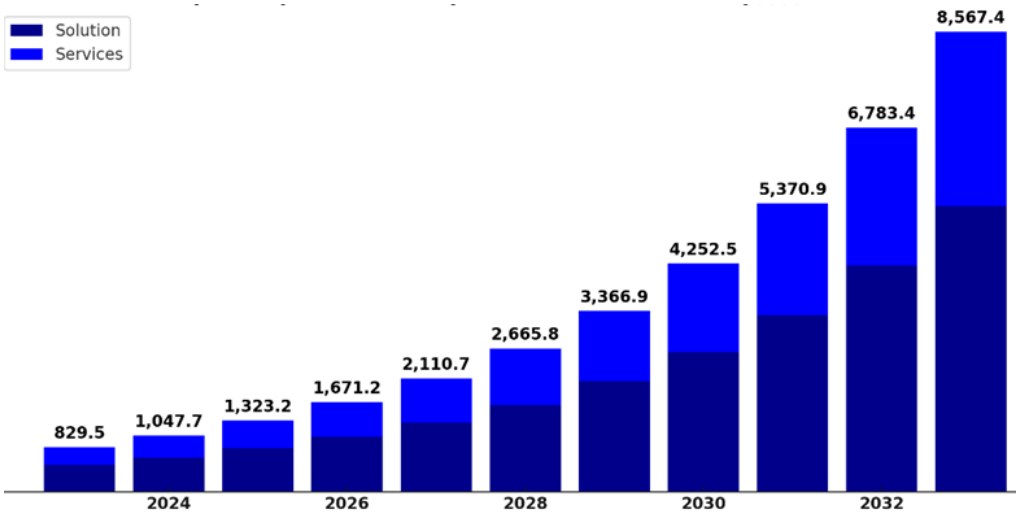

Fig. 3: Global market size for digital technologies, billion USD [7]

One of the primary technologies used in the digitalization of production is the Internet of Things (IoT). It involves communication among devices and equipment such that exchange of data happens in real-time. It is used in the industrial environment for monitoring and management of the equipment, systems, and processes on the production line. An illustration is that the sensors can monitor the condition of the equipment and report instantly that some maintenance or repair is required. This not only avoids breakdowns but also enhances the control of production resources, greatly increasing their efficiency.

Big data also has an application in the manufacturing process. Analytics systems allow for the collection and processing of data collected from various devices and using it for optimizing production. For instance, information about consumer trends, demand patterns, and process efficiency across the entire production cycle can be utilized. With ML and AI technologies combined, these systems aid in the creation of predictive models that optimize processes and enable more intelligent decision-making. For example, within production, it is possible to forecast material needs or consumption of resources in advance, cutting back on waste and raising planning accuracy.

A significant role in increasing value added in the manufacturing sector is also played by AI. It is being used in operations such as quality checking, equipment testing, and inventory control. They can spot patterns not so easily perceived and make decisions which had to be done through human input previously.

The digitalization of production processes has significant economic impacts, which can be seen both in the short and long term. Among the most dramatic is decreasing the operational cost. Through these technologies, automation of a majority of labor-intensive processes is feasible, reliance on human labor decreased, and possibilities of errors reduced. For example, in the course of producing, it becomes easier to exercise control over the consumption of energy, water, and other resources more effectively, leading to colossal savings and reduced costs.

In addition to this, it contributes to greater product quality and production flexibility. These technologies facilitate the reconfiguration of production lines at a high speed, adapting them to new specifications. As a result, it accelerates the time-to-market of new products as well as their conformity to consumers' expectations. For example, by using automated production management systems, organizations can changeover very quickly from the production of a given product model to another one without loss of efficiency. Furthermore, digitalization creates new opportunities for product customization. Due to it, companies are able to change production processes more precisely, enabling them to manufacture products that meet the individual requirements of customers.

Examples from large corporations adequately demonstrate the performance of implementing these technologies. General Electric is an example where digital solutions efficiently optimized production activities and increased equipment efficiency. Implementing the IoT and data analytics helped optimize operations and reduce maintenance costs [8].

Thus, the impact of digital technologies on value added growth is clear. Their implementation allows firms to significantly enhance their efficiency, reduce costs, and improve product quality. These technologies not only streamline current processes but also allow new business models to be created, creating further growth and strengthening market positions.

5. Economic and social aspects of technology implementation

In recent decades, the implementation of robotic and digital technologies has had a significant impact on production processes, which has serious consequences for the labor market and the economy as a whole. These changes are not just a question of production or product efficiency improvement. They also bring about a fundamental shift in employment patterns, investment into production, and long-term economic consequences.

Process automation leads to reduced demand for common human labor. This is evident particularly in sectors such as assembly, packaging, and quality checking, where robots take over the place of humans in performing repetitive and tedious work. The reduced demand for regular labor can lead to reduced employment in some industries. However, due to these changes, the evolving nature of the job is giving way to a new type that will require higher skills and supporting documents.

The World Economic Forum says that by 2025 an estimated 12 million new jobs with these technologies will be created [9]. By this, it should be emphasized that, in the long term, changes

in the labor market are not only a question of employment reductions but also of their transformation towards enhanced qualifications and specialization.

In addition, structural transformation in labor requires social justice, especially in high-unemployment nations or those with limited access to education. In this regard, the use of robotic and computer technologies can worsen the social scenario unless adequate workforce adaptation measures are taken. The problem is that the majority of employees may lack the qualifications to work under the new conditions, and without having complete training programs, they can lose their employment. Therefore, policymakers and businesspeople ought to endeavor to craft support programs that facilitate the transition of workers to new jobs, as well as create conditions for the successful embedding of innovative technologies in societies with varying levels of digital maturity.

Investment in capital in new technologies is yet another important factor in the introduction of such solutions. The move to more automated and digitalized production processes requires significant investments in equipment, software, and even in training of personnel. They are proving difficult for small and medium-sized enterprises, especially in conditions of economic uncertainty. However, for large enterprises, these investments are not only unavoidable but also profitable in the long term. They allow to react in real time to changes in demand and market requirements and so prove to be more responsive and competitive. Thus, corporations can establish long-term economic advantage warranting the initial cost.

Yet, with the entry of new technologies comes not only benefit, but also risk. One is over-automation, causing a loss in the flexibility of production and the adjustability of the firm to alterations in the outside world. This is possible, for example, when the manufacturing processes turn out to be ineffective for new products or when any unforeseen disruptions occur.

Technology aging is also an important problem. As technology develops, existing high-maintenance systems with high costs of modernization may turn out to be economically unviable. Firms therefore find themselves constantly investing in hardware and software upgrades, causing additional financial expenditures.

Hence, the implementation of digital and robot technologies, besides having an economic impact, has social significance. To enjoy the full scope of these technologies, it is crucial to consider their impact on the labor market, the cost effectiveness of investment in capital, and the danger of over-automation and obsolescence in technologies. In addition, the social consequences of these processes must be addressed with sensitivity to retraining the labor force and coping with social inequality. Only an integrated strategy to these issues will ensure a successful restructuring of production and sustainable economic growth within the context of technological changes (fig. 4).

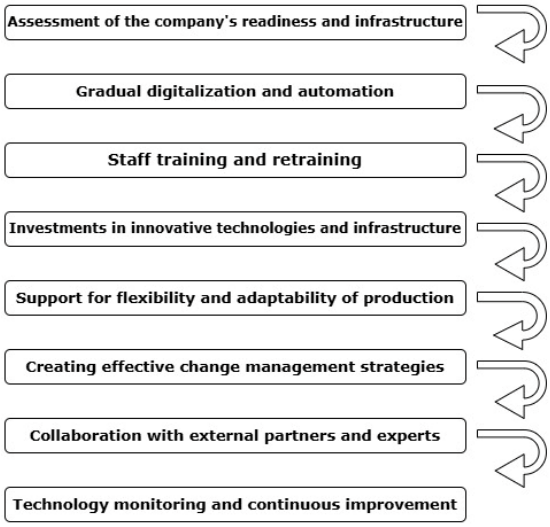

Fig. 4: Stages of successful implementation of robotic and digital technologies in production

Before implementing the introduction of information and robotic technologies, it is necessary to conduct a thorough assessment of the status of current company infrastructure. The procedure involves compatibility testing of existing systems and new technologies as well as reviewing existing production processes. One needs to think about identifying weak points in the production chain that are subject to exclusion by automation. Assessment should concern technical solutions and organizational aspects.

In the process of implementation, it is required to follow a phased nature. It is advisable to start with pilot projects, which will minimize risks and avoid significant disruptions in the production process. Implementation of new technologies requires enormous efforts in personnel training and retraining. They should not only master the skills of working with new robotic systems, but also learn how to use and maintain automated production lines. It is recommended to carry out regular training, qualification upgrading courses, and retraining programs.

Implementation requires huge investments in machinery, computers, and refurbishing infrastructure. The planning must begin with the examination of long-term profitability and economic impact on the firm. No less important is the establishment of flexibility in manufacturing after introducing new technology. Robots and automated equipment must adapt to changes in demand, production requirements, and product types. For this, it is necessary to use digital twins and monitoring systems, which provide round-the-clock control over production processes and help to adjust them in real time to changing conditions. For small and medium-sized enterprises, which can sometimes have very high costs for the installation of new technologies, cloud-based solutions are the best solution. They provide the use of new digital technologies without large capital investment.

The introduction of new technologies is inevitably associated with changes in the organization and work processes. It is necessary to develop effective strategies for managing them, which will include communication with employees, explaining the goals and stages of the introduction of new technologies.

The implementation process must take into account not only economic efficiency but also social and ethical considerations. One can suggest the development of corporate social responsibility programs for the support of redundant employees due to automation. Cooperation with external stakeholders, such as robotics and digitalization specialists and technology consultants, is a crucial point. This allows businesses to utilize expertise and best practices to accelerate the process of technology integration.

After the new technologies are implemented, it is important to continue monitoring their performance. Timely feedback collection from employees and production process analysis will help detect likely weaknesses in new system operation. It must be required that technologies' implementation becomes a continuous improvement process with the goal to adapt to market changes and internal business needs. Upkeep of systems up to date through regular adjustments alongside ongoing additions of cutting-edge solutions will enable competitiveness and productivity for the long run.

Thus, the introduction of robot and digital technologies requires an integrated approach combining technical, organizational, and social aspects. Transformation of the production process and long-term business development are possible only through deep analysis and successive implementation of technology and ongoing adaptation to changing conditions.

Conclusion

The application of digital and robot technologies in manufacturing shows the future potential of transforming added value through improved productivity, lowered operating costs, and improved product quality. With the convergence of automation, AI, big data analysis, and the IoT, manufacturing operations are being optimized for efficiency, accuracy, and responsiveness to market demands. They enable reduction of resource waste, optimization of production time and enhanced chances of customization, and therefore competitiveness and long-term sustainable economic performance. The examples from major industrial players confirm the strategic importance of investing in innovation as a source of long-term economic advantage.

With this, the transition to high-technology production systems also has profound socio-economic consequences. As some of the older forms of employment are gradually disappearing, new employment patterns are emerging that require greater skills, and retraining and education become essential components of industrial policy. Moreover, ethical, and regulatory considerations must be tackled to allow for balanced growth, above all the mobility of labor and access to technological gains on a level basis. A planned implementation that integrates technical readiness, human resource capacity development, financial planning, and stakeholder engagement is necessary in order to achieve not only economic effectiveness but also social sustainability in the age of the internet.

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