Theoretical Aspects of Technology Development and Transformation Processes in the Labour Market

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Abstract. *The present research is directed towards the analysis of the relationship between technology, on the one hand, and economic development and the labour market, on the other. The research also focuses on characterising different approaches to determining the level of technology development in the economy. The investigation of the impact of technology on the economy and on the labour market as its component is relevant, because technology is the factor that causes the most debate in the modern world. Additionally, technological development is becoming increasingly dynamic, necessitating constant updating of theoretical approaches to analysis. These approaches may be employed in subsequent research endeavours. The following methodologies were employed in the analysis of the labour market and technological progress: analogies, abstraction, concretisation, the historical method, analysis and synthesis, comparison and grouping. The analysis of the impact of technology on economic development focused on five areas: production growth, economic growth, structural transformations in the economy (including employment), growth in household incomes, institutional changes and the reduction of negative environmental impact. It was found that technology has a positive impact on all factors except environmental impact. The positive impact of technology on all factors except environmental impact was substantiated. The efficacy of technological interventions in enhancing environmental quality is contingent upon their judicious implementation. Furthermore, the study has demonstrated a correlation between technological advancement and economic growth. The process of economic development enables the generation of resources by the economy, which can subsequently be allocated towards new initiatives and the acceleration of technological advancement. Furthermore, technological development has been demonstrated to be a contributing factor to economic development. The analysis of the mechanisms of labor market functioning includes the following: supply and demand, labor productivity, and government policy. The impact of technology on the labour market has been positive throughout history. The evidence suggests that they have contributed to productivity growth and the transition to lighter types of employment. However, in the contemporary era, technological advancements have the potential to diminish employment opportunities in the domain of intellectual labour, concomitantly generating roles that are characterised by a high degree of specialisation and a limited capacity for career progression. Consequently, further research into the impact of automation and AI on unemployment is pertinent, particularly in the context of developed and developing countries. The article also identifies approaches used to determine the level of technological development of the economy. The factors determining the technological level are as follows: human capital and skills, R&D investments, institutional development, international co-operation, infrastructure, corporate culture, and government policy. Furthermore, the study identified complex indicators and indices. This analysis facilitates the selection of the most effective combination of approaches for ranking economies by technology level, a prerequisite for subsequent research. Furthermore, the relationships identified in the study are a prerequisite for an empirical analysis of the impact of technology on the labour market.*

Keywords: *technology, labour market, economic development, innovation, productivity.*

JEL Classification: *E24, E29, J23, O10*

1 Introduction

Technological progress is characterised by increasing dynamism, which gives rise to certain doubts and controversies about future transformations. One of the areas affected by technological advancement is human labour. The impact of technology on the labour market is a contentious issue in the modern world. Consequently, the analysis of the impact of technology on the labour market is currently a priority area for research. A theoretical framework is needed to investigate this relationship. This requires an analysis of the impact of technology on the economy, an examination of the nature and principles of the labour market, and an investigation into modern methods of measuring technological development.

The impact of technologies on the economy and labour market has been analysed by many scholars at different times. These scholars include Arthur W. B. (2009), Bonciu F. (2017), Mokyr J. (1990), Solow R. M. (1957), Autor D. H. (2022), Romer P. M. (1990), and others. It is evident that international organisations such as the World Bank, OECD and ILO are also paying considerable attention to the problem. Concurrently, further research is required to analyse the indicators of technological development and the impact of technology on labour at the present stage. A further novel development is the study of economic development in terms of its components.

The objective of the present study is to analyse the interrelationships between technology, economic development and the labour market. It is imperative to ascertain the objectives of the research:

– To define the concept of “technology” and determine its impact on economic development in a comprehensive manner, for which it is necessary to identify the components of economic development;

– identify the main ways in which technology affects the labour market, as well as the mechanisms at work within it;

– to analyse existing approaches to determining the technological development of the economy for further empirical research.

The focal point of this inquiry lies in the economic structure and the labour market as an integral component thereof. The subject under discussion is the impact of technological progress on the economy and the labour market. The following research methods were employed: the historical method (necessary to understand the context of the current state of the labour market), analysis and synthesis (allowing to understand the relationship between indicators), comparison and grouping (necessary to study indicators of technological development), analogies, abstraction, concretization (in particular, the definition of concepts).

2 Technology and its Impact on the Economic Development of Countries

The concept of technology is defined as the practical implementation of knowledge in a particular sector (Arthur W.B., 2009). Alternatively, they are regarded as alterations in the utilisation of information within the production process, with the objective of enhancing efficiency. This can result in the production of a specified volume of products with a reduced resource expenditure or the development of superior or novel products (Mokyr J., 1990). It is important to note that key components of the process of developing and implementing modern technologies are: the provision of education to scientists, scientific research itself, innovations and the process of their implementation in the economy.

The concept of "economic development" is intricate, and encompasses not only the augmentation of production. This is in contradistinction to the concept of "economic growth". Economic development is a broad concept, and as scholars have defined it, encompasses components such as output growth, transformations in the structure of the economy, growth in income and welfare, institutional changes in the economy, and even the environmental component (Figure 1).

In considering the impact of technology on the initial component of economic development, the Cobb-Douglas production function is worthy of mention, as it demonstrates the dependence of output on labour, capital, and the level of technology in the economy. Concurrently, technological advancements have been shown to be positively correlated with output levels.

R. Solow's neoclassical model is one of the key theories of economic development. The scientist found that traditional factors of production, such as capital and labour, could not fully explain high rates of economic growth, and so he introduced the concept of total factor productivity, which primarily reflects technological progress. In the United States, up to half of economic growth since the end of World War II has been attributed to technological progress and accumulated knowledge (Denison, 1974). Similar calculations for other countries have also demonstrated the significant impact of TFP on economic growth.

In his theory of endogenous growth, Paul Romer emphasises that long-term economic development is determined by the level of human capital. Human capital is defined as the set of knowledge, innovations and ideas used in business, science and

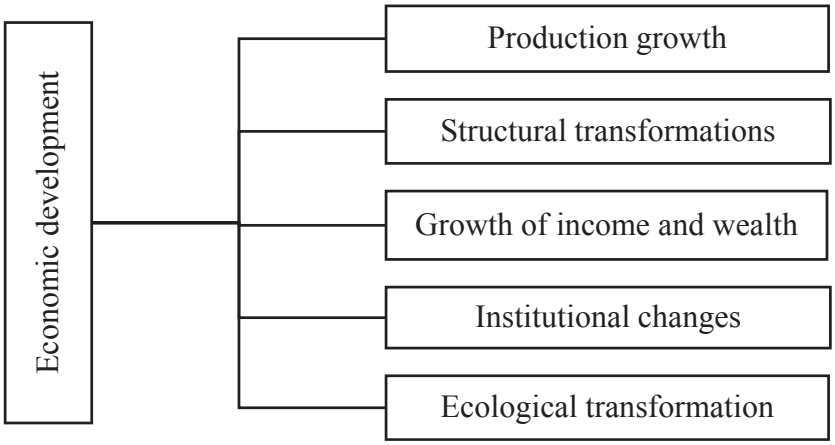

Figure 1 Components of the concept of "economic development"

Source: compiled by the author

public administration. Ideas are a source of growth because they generate technological innovations that increase productivity (Romer P. M., 1990).

Another aspect of economic development that is mentioned by most scholars is reducing poverty and increasing income. The neoclassical theory is the key economic theory of wages that takes the technology factor into account. According to this theory, wages are determined by the value of an employee's contribution to production, or their marginal product (Wicksteed P. H., 1932). The advent of technology has been shown to engender a number of key consequences, chief among which is an enhancement in the productivity and efficiency of the labour force. This, in turn, has been demonstrated to result in an augmentation in the contribution of individual employees to the final product. Consequently, as technology advances, wages tend to rise.

Recent studies show that the wage gap is widening in developed countries. The reduction in middle-paid jobs has led to an increase in high- and low-paid jobs. This is particularly explained by international labour migration (Kolev & Saget, 2010).

According to human capital theory, wages directly depend on an employee's qualifications and education (Mincer, 1974). Therefore, it could be argued that technological advances have a positive impact on income levels, as they require the workforce to improve their qualifications and skills.

The correlation between institutional change and technology is particularly evident in the study by B. Karlsson and R. Stankiewicz (1991). In it, they introduce the concept of a technological innovation system, emphasising the interaction between different stakeholders, such as firms, research institutions and governments, and the effect of this interaction on the development and diffusion of new technologies. The role of institutional frameworks in facilitating or impeding these processes is of paramount importance. The development of institutions and technologies occurs in a concurrent manner. The development of well-developed institutions has been shown to facilitate technological development, while also enabling the adaptation to and utilisation of technology.

Another component of economic development is structural changes in the economy, such as a reduction in the share of agriculture and an increase in the share of the service sector. Historically, technological advances have been the primary catalyst for these processes. The industrial revolutions that have occurred to date have increased productivity, thereby reducing the demand for labour in certain sectors. At the same time, however, new jobs have been created in other industries (Bonciu, 2017). Initially, this resulted in labour moving from agriculture to industry, and subsequently to the service sector. In the contemporary economic paradigm, the quaternary sector of the economy is distinguished by its association with the processing, generation and utilisation of information. This encompasses a wide range of activities, including information, insurance, financial services, as well as knowledge-based business services, research, education and ICT (Kenessey, Z., 1987).

Theories of structural transformation predicted the convergence of employment structures in countries with different levels of development. Nevertheless, extant research demonstrates significant discrepancies in the labour markets of

developed and developing countries. The latter group has been shown to exhibit a higher concentration of professions that are susceptible to automation (Ganuthula V.R.R. and Balaraman K.K., 2025).

In modern society, the environmental aspect of economic development is becoming increasingly important. When considering the impact of technology on the environment, it is worth acknowledging its ambiguity. According to the production line theory, the greater the volume of products or goods created, the greater the use of resources and the greater the environmental impact. Consequently, economic growth is considered a cause of environmental pollution (Schnaiberg, 1980). Technology has a significant direct impact on economic growth. Conversely, a number of modern theories consider technology to be beneficial for the environment. The theory of ecological modernisation, for example, suggests that environmental problems can be solved through technological innovation, economic growth and institutional reforms within existing systems (Mol & Sonnenfeld, 2000). Therefore, if technologies are applied correctly, they can have a positive impact on the environment.

To summarise the review of the main economic theories, it can be noted that despite methodological differences in research, economists recognise the connection between the growth of knowledge, technical innovation and long-term increases in labour productivity, gross domestic product and income.

Contemporary economists acknowledge technological progress as a contributing element to economic advancement, with research and development (R&D) being recognised as a pivotal factor in facilitating this progress (Cohen L.R. and Noll R., 1991). It is evident that a nation's investment in technology, encompassing both financial resources and human capital alongside institutional infrastructure, directly correlates with the magnitude of its long-term impact. This phenomenon is evidenced by the escalating levels of technological development, concomitant economic growth, enhanced living standards, and economic transformation. This, in turn, provides the financial resources necessary for further investment in the technology sector (Borrus & Stowsky, 1997). Consequently, a positive cycle emerges in which technology and economic growth reinforce each other. Therefore, the impact of technology on economic development is reciprocal (see Figure 2).

Due to the rapid advancements in technology, the analysis of various aspects of the impact of innovations on the economy, including the labour market as a constituent element, is becoming increasingly pertinent.

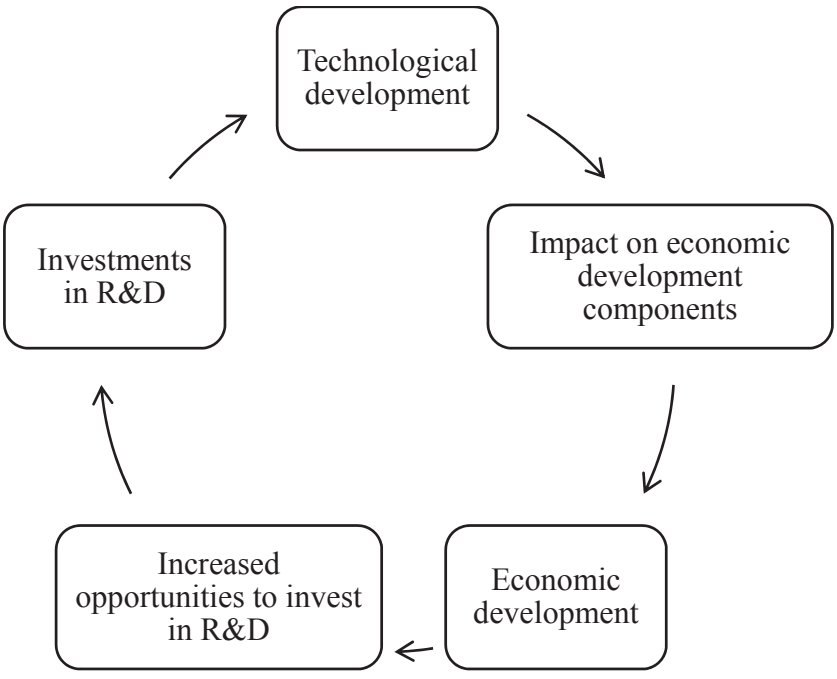

Figure 2 Diagram of the impact of technology on economic development

Source: compiled by the author

3 The Nature of the Global Labour Market and the Drivers of Transformation

Economists define the nature of the labour market as a system in which workers offer their labour and employers demand it, with employment conditions being set by the interaction of these two factors. Conversely, contemporary approaches are increasingly emphasising the labour market as a social institution influenced by economic, political and technological factors (Saha J. M. and Rowley C., 2014).

The components of the labour market are employees, or the labour force, and employers. On the other hand, there are labour and wages. The processes that take place in the labour market can be explained simply as employers hiring workers from the labour force who have the specific characteristics and qualifications they need, and paying them for their work (Pavliuk T.I., 2018).

The demand for labour is determined by the prevailing economic and employment conditions, and is manifested through the hiring process. Conversely, the labour supply is defined as the total number of employed and unemployed individuals within the economy. The interaction of these two components affects the movement of the economically active population between business activities in relation to jobs distributed by sectors, territories, demographics, and professional qualifications (Kotlia A., 1998).

Classical labour market theory states that labour markets tend towards equilibrium when labour supply and demand coincide (Smith, A., 1776). This theory assumes that wages and prices are flexible, enabling the market to swiftly adapt to shocks. Labour is fully mobile and unemployment is largely voluntary.

An alternative approach to the labour market is reflected in the Keynesian theory. As posited by this theory, a decline in the demand for goods and services is a contributing factor to a decline in production and an increase in unemployment. The labour market is inherently incapable of achieving equilibrium; government intervention is therefore required for the effective functioning of the market (Keynes J.M., 1936). In the context of an economic downturn, state regulation measures should be focused on stimulating demand and the economy, with a particular emphasis on increased public spending and tax cuts. The Keynesian theory is more suited to real conditions than the classical theory, and consequently continues to underpin economic policy in numerous countries. The factors that influence the labour market are aggregate demand and government regulation measures aimed at demand.

The theory of the segmented labour market posits the division of the labour market into two segments: the primary (well-remunerated jobs, opportunities for professional development) and the secondary (low-skilled, unstable jobs) market (Doeringer P.B. and Piore M.J., 1970). The aforementioned theory posits that institutions and power dynamics exert a significant influence on the labour market. In the theory of effective wages, labour productivity and the benefits used by employers are the factors that influence the labour market (Shapiro C. and Stiglitz J.E., 1984).

Consequently, scholars acknowledge that the labour market is influenced by numerous factors. Given that the focal point of this study is the impact of technology on the labour market, it is worthwhile to focus on the mechanisms of technological progress.

Despite the fact that technological progress at all stages has been accompanied by structural shifts in the labour market and productivity growth, the nature of these changes has varied considerably. There is a tendency to transition from physically demanding occupations to less strenuous roles, a shift that occurred during the initial phases of the first and second industrial revolutions. This was followed by a transition to roles that demand more intellectual faculties, a transition that took place primarily during the second and third industrial revolutions. Concurrently, the fourth industrial revolution has engendered the possibility for the automation of not only physical but also intellectual work for the first time (Bonciu F., 2017). Recent research suggests that the impact of AI may be fundamentally different from previous waves of technological change, potentially affecting tasks that were previously considered immune to automation. Albrieu (2021) posits that the new jobs that will arise as a result of these changes will be concentrated in areas where it is impossible to provide mass employment. Furthermore, these roles, for instance in the domains of artificial intelligence, science, or research, demand a high level of qualifications and intelligence, which poses a significant challenge to the general population in terms of adapting to change.

As even D. Ricardo (1817) acknowledged, the introduction of machines, while undoubtedly beneficial to society as a whole, has the potential to be deleterious for certain classes of workers. Keynes (1936) proposed that the phenomenon of technological unemployment arises from the discovery of methods to conserve labour that outpace the rate at which novel applications for labour can be identified. In the contemporary context, this issue is particularly highlighted by

network models that demonstrate the impact of automation on occupational mobility. The objective of the present study is to investigate the redistribution of labour by comparing the number and structure of vacancies, job seekers, and wages.

D. Autor's research indicates that 60% of contemporary employment is in professions that were not in existence in 1940, and that more than 85% of employment growth over the past 80 years has been driven by technological innovation (Autor D.H., 2022). According to forecasts, the demand for specialists in the sectors of healthcare, education, personal services and household care, as well as in knowledge-intensive sectors, is expected to grow. Consequently, employment in the quaternary sector of the economy is projected to expand. Concurrently, a decline in employment in unskilled services is anticipated. This suggests that the effects of the Fourth Industrial Revolution will be more evident in economically developed countries, where employment in the service sector, which is most amenable to automation, prevails (Saoudi H., 2021). It is evident that businesses are already leveraging automation in their operations, and this trend is set to persist. The key requirements for the contemporary workforce are becoming the ability to learn, knowledge of digital technologies, and the qualifications of expected employees are increasing. Consequently, the government's role in this regard is to implement policies that encourage the development and enhancement of the workforce's skills, both within enterprises and through state-sponsored initiatives.

4 Approaches to Measuring the Technological Development of the Economy

The classical economists did not engage with the concept of technological development in the modern sense. However, Adam Smith proposed that an increase in production per worker and specialisation are indicative of technological progress (Smith A., 1776). Keynes established a correlation between the increase in productivity, the utilisation of machinery in production, and the rapidity with which the economy incorporates new knowledge into technological advancement (Keynes J.M., 1936). According to R. Solow's theory, the main indicator of a country's technological level is total factor productivity (TFP), which is the productivity of production factors (Solow, 1957). According to Romer (1990), the main indicators of technological progress are human capital, the number of patents and R&D investments.

Today, technology is defined as a complex concept that connects with other areas. The level of technological development is reflected in economic, political and even environmental activities. Therefore, it is worthwhile analysing the modern indicators of technological development used by international organisations and educational centres.

Single-factor simple indicators include the following World Bank indicators: research and development (R&D) expenditure, charges for the use of intellectual property, the share of high-tech exports, the number of patents and the number of researchers in R&D. An alternative approach is reflected in the World Population Review's indicator of the number of computers per 100 people. The International Telecommunication Union disaggregates this indicator by type of technological device and publishes a number of indicators that characterise the technological skills of the population. The disadvantage of such indicators is that they are complex to calculate.

In the contemporary era, artificial intelligence represents a pioneering technological advancement. Consequently, the innovativeness of the economy can also be determined through the utilisation of AI. The European Union Statistical Office is responsible for the annual calculation of the percentage of enterprises that use artificial intelligence in their business. The Center for Security and Emerging Technology is responsible for the calculation of the Country Activity Tracker. It estimates the amount of research, scientific connections between countries, the number of research organisations, patents, and investments in AI development.

An alternative approach would be to assess the technological development of public administration and human capital. The indicators that characterise it include the e-Governance Development Index and the Human Capital Index from the United Nations, the Digital Economy and Society Index from the European Commission, and the IMD Digital Competitiveness Index.

The Global Innovation Index, developed by the World Intellectual Property Organisation (WIPO), is a comprehensive indicator of an economy's technological development. It takes into account factors such as human capital, science, infrastructure, market and business development, knowledge and technology outputs, and creative results (Global Innovation Index, 2024).

A thorough analysis of the varied approaches to defining technological development in the economy enables us to draw conclusions about the factors that influence the level of technology in a given country (see Figure 3).

The primary factor under consideration is human capital and education, given that the skills, level of education, and professional training of the

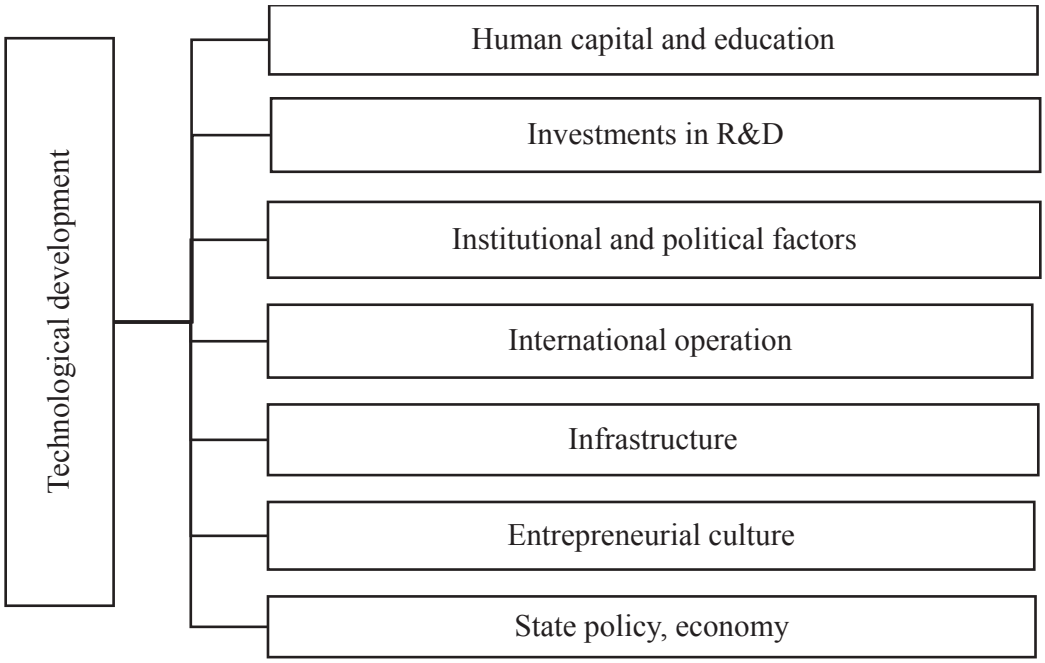

Figure 3 Factors that influence the technological development of the economy

Source: compiled by the author

population are fundamental to both the creation and adoption of technologies (Nelson R.R. and Phelps E.S., 1966). These factors are reflected in the Human Capital Index, the Global Innovation Index, the Digital Economy and Society Index, and the ITU indicators.

Investments in research and development are also important. After all, public and private R&D expenditure directly drives innovation and technological progress (Griliches, 1998). This is supported by P. Romer's theory and indicators from the World Bank and other international organisations.

According to Acemoglu and Robinson (2012), institutional and political factors (such as institutions, intellectual property rights, legal systems and political stability) create an environment that either promotes or hinders innovation.

International co-operation is also important for creating and applying innovations, as it enables the use of inventions from other countries. Openness to trade enhances domestic technological potential (Coe D.T., Helpman E. and Hoffmaister A.W., 2008). This is confirmed by indicators developed by international organisations.

Reliable communication networks, energy systems, transportation and digital communications (i.e., physical and digital infrastructure) are essential for technological development, as is the cost of using them. Without this infrastructure, the adoption of technology remains limited, even when knowledge is available (World Bank, 2016). Several of the indices under consideration (including the Global Innovation Index) take this factor into account.

An entrepreneurial culture plays a significant role in introducing and diffusing new technologies within an economy. The presence of dynamic firms and start-ups, as well as an innovative culture, accelerates technological progress (Audretsch & Thurik, 2001). This group of factors also encompasses the social attitudes and cultural values that influence how innovations are perceived and applied.

Government innovation policy and strategic planning also affect the level of technology in a country, as does government support. Many fundamental technologies have resulted from government innovation initiatives (Mazzucato, 2013). Therefore, it is worth considering factors that demonstrate the degree to which public administration is digitalised, as well as indicators that characterise economic policy and are included in a number of indices.

Despite the influence of economic factors on technological development, such as the availability of credit, capital, and economic policy, it was determined that these factors would not be categorised separately. This decision was made on the basis that economic productivity growth and economic development are not factors but consequences of technological development. However, it should be noted that these indicators can also serve to measure the level of technology.

5 Conclusions

Technology is defined as a change in the application of knowledge that leads to increased output at a lower cost. It has an impact on all aspects of economic development. It increases productivity, thereby contributing to growth in production. In theory, it raises workers' incomes, but in practice, some low-paid jobs remain. Technologies contribute to the development of institutions, which in turn contribute to technological progress. Structural changes to the economy are also a consequence of technological change. However, the impact of technology on the environmental aspect of economic development is only positive when technology is applied correctly. Otherwise, production growth leads to increased environmental pollution.

More economically developed countries can invest more in research and development (R&D), accelerating the development of technologies. This creates a cycle in which economic and technological development feed off each other.

The labour market can be viewed as a self-regulating mechanism. At the same time, however, it can be seen as an area that requires government intervention. It operates through mechanisms such as balancing supply and demand, structural changes, and the transfer of labour from one industry to another. Technological progress contributes to this. For the first time, modern transformations are threatening employment in services and intellectual labour. Qualification requirements for employees are growing. At the same time, the quaternary sector of the economy is showing promise.

There are various ways of measuring technological development. Some focus on the structure of exports, the number of researchers and R&D investment. Others measure technological development through the use of AI, the technological development of public administration and human capital. All these methods are used to identify the most technologically advanced economies for further analysis. Factors influencing technological development include investment in science, human capital, institutional and political factors, infrastructure, entrepreneurial culture and public policy.

The impact of technology on unemployment is still a matter of debate. Scholars also hold ambiguous views on the differences in the impact of technology on developed and developing countries. These issues require more detailed consideration in future.

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