
TECHNOLOGICAL UNEMPLOYMENT IN THE CONTEXT OF AUTOMATION AND ROBOTIZATION

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Abstract. Many modern analyses of the nature and consequences of the fourth industrial revolution warn of the possibility of a serious blow to employment as a result of the comprehensive penetration of new technological achievements. Their most important axes of manifestation are automation, robotization, digitalization, digital transformation and the development of artificial intelligence. In this sense, with the present development, we aim to trace the development of economic thought regarding the justification of the causes and conditions for the occurrence of technological unemployment, on the one hand. On the other hand, to channel the results of empirical studies proving or rejecting the possibility of the manifestation of technological unemployment. To achieve this goal, a literature review is made of various theoretical concepts regarding the causes of changes in employment, as well as a presentation of results from a number of empirical studies in this scientific field.

Keywords: technological unemployment, automation, robotization.

JEL: E24, O11, O33

Introduction

Technological progress could become a source of unemployment not only when the demand of labor is reduced as a result of the replacement of humans with machines. It could also create obstacles to process of adapting people to jobs. In particular, the achievements of the Advance of science and technology have an impact not only on the volume of employment, but also on the composition of the workforce. To overcome the resulting imbalances between the demand and supply of labor, a redistribution of the workforce at professional, territorial and inter-company levels is necessary. Some occupants become obsolete and new ones emerge in their place. This process is a consequence of demands on the education and skills of workers. In addition, new technologies increasingly require the relocation of labor from regions where it is no longer needed to others that need the right type of labor. Companies that do not increase the technological level of their production begin to lay off workers and innovative companies create new employment opportunities. A consequence of this process is the migration of labor from one firm to another.

In the case of sudden technological leaps, adaptation to them can take a much longer period of time and their effects take on painful forms. Retraining, mastering new professions, raising the level of education. Changing place of residence, changing place of work are actions that take time and are accompanied by serious costs for people. In this sense, as a short-term phenomenon, technological unemployment is a real problem and, to one degree or another, is always present as a phenomenon in modern economic conditions.

There has long been debate in the scientific community about whether technological unemployment overlaps with frictional unemployment or not. When the answer to the question is yes, it implies an assessment of its distribution and, and above all, the possibilities for its not so slow decline.

Some developments note that technological innovations actually cause a temporary rise in unemployment, particularly pronounced in the first few years after the start of technological changes. After this period, however, it returns to its starting point, even settling at lower levels. In this regard, it should be noted that such a short-term rise in unemployment could also be observed when in the long term rise in unemployment could also be observed when in the long term scientific and technological progress plays the role of an accelerator of labor demand.

1. Technical progress and changes in the labor market

A number of factors influence the level and duration of technological unemployment. The most important of these are:

- The scale of required workforce repositioning – determined by the speed, depth and scope of technological change;
- The strength of the gap between the quality requirements of old and new technologies;
- The degree of flexibility in labor markets on which the process of repositioning of the workforce depends and the speed of its progression.

Here it should be noted that technological unemployment is not a one-time phenomenon. The dynamics of technological change today are high. New breakthroughs are constantly being made in various scientific fields, which find practical manifestation in production and consumption. This means that technological unemployment should be seen as a permanent phenomenon that can have both short-term and long-term effects. What is more, at the current stage, the speed of technological change seriously exceeds the rate at which firms and workers are able to adapt to it. In other words, under certain conditions, the scientific and technological progress can be a cause for change even at a natural level.

One of the important consequences of the serious dynamics of technological change is the rapid aging of the knowledge and skills of the

workforce. This is a motivating factor for companies to quickly get rid of workers with outdated knowledge and skills, on the one hand, and, on the other hand, to more actively search for and hire new ones. In conditions of frequent technological change, the expected length of time between workers and the positions they occupy will decrease more and more. In other words, the rate of aging of knowledge and skills becomes ever higher. At the same time, because the scientific and technological conditions create conditions to increase labor productivity, the productivity of each additional job created will grow. This incentivizes firms create new employment opportunities.

In situations where the third factor is less effective than the first two, the introduction of new technologies will cause an increase in the natural level of unemployment in the economy.

In view of the circumstances presented, it could not be said that they were predestined. Scientific and technological advances have different forms of manifestation. In some cases, the closure of existing jobs and, in others it causes their renewal (Monroy, S., Moreno, M., I. Santos 2015). Under such conditions, workers adapt to the demands of new technologies, updating and supplementing their knowledge and skills, and retain their employment. The above points to the conclusions that **scientific and technological advances(STA) result in forms in which jobs are closed, the natural rate of unemployment increases. Conversely, when the manifestation allows the renewal of jobs, it decreases.**

One of the essential questions that preoccupy researchers of the problem of technological unemployment and the impact of STA achievements on employment is the determination of the rhythmicity in which periods to excess unemployment are taken into account. According to various authors in the economic history of the world, they could not give concrete examples in which the acceleration of the technological progress caused a sharp increase in unemployment (Kwiatkowski, E., M., Bölükbaş. 2024: 185-203; Saka, H. 2021). The advent of automobiles at the beginning of the 20th century did not cause mass unemployment among plumbers, blacksmiths and locusts. In the same sense, the advent and deployment of computers in manufacturing and the home does not entirely deprive typists of work. These examples are proof of the thesis that there is **a relative comparability between the speed of the technological introduction and the rate of adaptation of the workforce to them.**

Going back to the economic history of the world, it can be said that the implementation of the achievements of the STA is not carried out explosively, but rather is distributed over time. In some cases, in shorter periods, and in others in longer periods. This makes the process of adaptation of firms and the workforce to them smooth and in this basis – entirely

possible. In this sense, conditions are created to avoid sharp shocks in unemployment caused by purely technological factors.

In recent years, there has been a tendency among researchers on this issue to link labor market phenomena and processes in developed countries primarily to the influence of technological factors (Abbasabadi, H. M. & Soleimani, M. 2021). For example, Acemoglu, D., P. Restrepo 2018 give a purely technological explanation for the high level of unemployment sustained in the U.S economy after the Great Depression. At present stage, when the speed of technological change is significant, unemployment in developed countries has fallen to levels lower than natural ones.

Today's discussions on this topic seek to answer the question whether a serious rise in technological unemployment can be expected in the near future, as some researchers predict (Atalay, E., Phongthientham, P., Sotelo, S., D. Tannenbaum 2018: 48 – 67). When conducting a thorough analysis of the changes in the production system caused by new technologies, the dynamics of employment and unemployment, and the processes of formation and adaptation of human capital to the new conditions, the answer to the question would be that this is unlikely. Evidence for such a thesis can be found in several directions. First, the modern dimensions of technological progress have to do not so much with the elimination of the jobs as with their renewal. For example, computerization has triggered a large-scale process of taking functions away from humans and giving way to machines, especially in routine operations. Using statistical information on the German economy between 1979 and 1999 A. Spitz-Oener found that 99 percent of the replacement of people by computers occurred at the expense of a reduction in routine operations performed within existing occupations. At the same time, only 1 percent was at the expense of the disappearance of occupations that were entirely routine (Spitz-Oener A. 2006:235-270).

Second, much of the pessimistic predictions of a boom in technological unemployment are based on an overly simplistic understanding that employment in an economy is divided solely into low- and high-skilled ones. Assuming that new technologies limit the demand for the former but increase that of the latter, it would be possible to conclude that large-scale technological unemployment is inevitable. This is because machines are displacing low-skilled workers who could not claim to take up positions that require them. This differentiation of the labor force has been adopted primarily to simplify the analysis. In practice, there is a much more complex differentiation of the labor force, on the basis of qualifications. It must be taken into account here that it is not impossible for labor resources located in the lowest segments of the professional hierarchy to rise higher. At the same time, workers who occupied a higher position in the qualification hierarchy could move to the top. This leads to the conclusion that **the possibility of**

such chain substitution between different groups of workers reduces the risks of large-scale technological unemployment.

Thirdly, the process of introducing new technological advances could face some purely engineering, regulatory, social and ethical hurdles to slow its development. For example, the transition to fully autonomous cars is impossible without changes in the regulatory framework liability for road traffic accidents. As is well known, changes in legislation can sometimes take years. Given that the process of penetration of new technologies is smooth, the adaptation to it by the labor market can pass successfully and without much disruption. This once again supports the thesis that a serious increase in technological unemployment should not be expected in the near future.

The period after 2007 is considered to be one of the weakest in the economic history of developed countries. Since the beginning of the 20th century, the rates of growth of GDP and of total factor productivity (TFP) have been reported. This suggests a slowdown in the dynamics of the TFP. The reasons can be found in the financial and economic crisis of 2007 to 2013, as well as the Covid-19 pandemic. In their study, Bergeaud et al. 2017 form dynamic rows of data on average annual GDP and TFP in developed countries for the period from 1890 to 2015. From the data presented in the diagrams in Figure 1, the following periods of slowdown in the rates of the two macro variables can be outlined. The first long-term slowdown in productivity growth occurred in the years immediately before the financial crisis after 2007. Even after the recovery of economic dynamism, the TFN remained low in developed countries compared to previous periods and for the UK it was negative in the period 2005-2015. Recessions are known to have a negative impact on the opportunities for economic growth but the reasons for their negative impact on the pace of technological renewal have been sufficiently well analyzed. What is more, the data of the U.S. economy show that the 1930s, the time after the Great Depression from 1929 to 1933, were the most innovative period in the country's history. (Field A. J. 2003: 1399 – 1413)

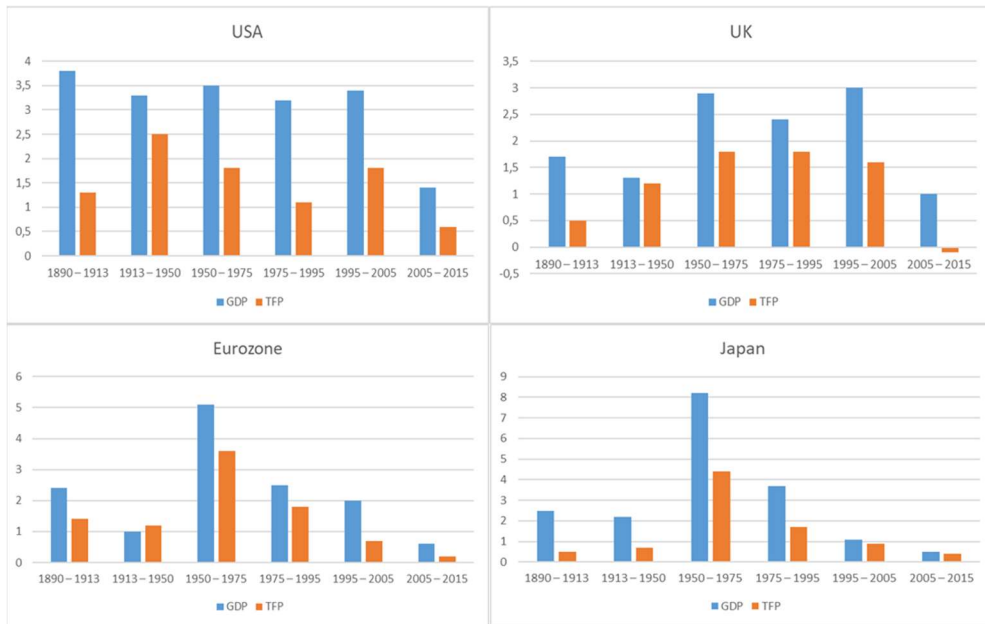


Fig. 1. Rate of change in average annual GDP and total factor productivity (TFP) in developed countries for the period 1890 – 2015, in %

Source: Bergeaud A., Cetto G., R. Lecat. (2017). Total factor productivity in advanced countries: A long-term perspective. International Productivity Monitor, No. 32, Spring, pp. 6-24.

Modern researchers are united around the understanding that the sharp deterioration around the understanding in the dynamics of GDP and TFN observed in developed countries is not a short-term phenomenon. In the first decade of the twenty-first century, a prolonged downward trajectory of economic growth was observed. The opinions of the researchers are united that the reasons for this is the slowdown in the pace of TFN, i.e. of technological innovation. Of the American economists, only Brynjolfsson and McAfee, counted among the group of convinced techno-optimists, continue to hold the position that in the very near future the annual growth rates of GDP and TFN will accelerate to an average of 2% (Brynjolfsson E., A. McAfee 2011). More than 10 years have passed since this forecast was made, but similar indications have not been taken into account. Many other authoritative researchers on economic growth are in the opposite position. Their expectations are for an even greater slowdown in GDP growth and a decline in TFN growth and a reduction in its average annual growth rate to between 0.5 – 1%. According to their estimates, in the most optimistic scenario, the U.S. economy would return to the levels of these indicators from

the two decades of stagnation between 1972 and 1995 (Diamond, J. W., G. R. Zodrow 2021). Taking this into account, it can be said that a technological unemployment boom is not expected in the near tear. If the rates technological progress indicated in the researchers' projections are even lower than their historically established levels of previous periods, it will be easier for firms and workforce to adapt to them.

Technological development is a difficult process to predict. It is possible to have many unexpected events than change the situation very quickly. Entirely new technologies are likely to be developed somewhere, the emergence and implementation of which will cause radical and shocking changes. An example in this direction is the explanation of finding a new energy source that would completely replace oil. The moment it is presented to the world and begins to be used, this will lead to revolutionary changes, such as the appearance of electricity in the 19th century.

In discussions if technological unemployment, it is often forgotten that new technologies have an impact not only on the demand for labor, but on its supply. If labor demand effects are still in the realm of expectations and probabilities, then those in supply are already a reality.

Along with the monetary losses associated with the lack of income, the unemployed also suffer a number of non-monetary harms. They are primarily psychological in nature and manifest mainly when they fall into a situation of enforced idleness and social isolation. Thanks to the development of information and communication technologies today, the unemployed do not lose their social contacts. Through social networks and through various Internet applications, they can maintain communication with other people. The more the unemployed people begin to value their free time, the more their motivation to seek paid employment opportunities in the market decreases. In other words, an unintended effect of the spread of new technologies can be identified as the decline in the employment rate, particularly characteristics of young people today.

The data on the US economy show that under the influence of the development and penetration of information and communication technologies (ICT) in recent years, the labor supply curve for all age groups of the working population has shifted in a downward direction. This is most serious in the case of young men aged 21 to 30 with a low level of education. Between 2000 and 2015, their employment rate decreased by 10 percentage points – from 182 to 72 %. At the same time, the proportion of those who had no employment in the previous years rose sharply – from 10 to 22%. In terms of the average length of time worked by a person, this group had fallen to 300 hours on average per year. In this sense, the balance of time had changed as follows: the time to work in a traditional workplace in a place had decreased to 3.5 hours and working from home was almost 2 hours a week, the time for

education and training had increased. Even more interestingly, young low-educated men increased the time they spent in front of the computer to 6.5 hours per week. This was mainly used for video games – 5 hours more than previous period. According to the economic estimates, $\frac{1}{4}$ to $\frac{1}{2}$ of the total reduction in time worked in this group of individuals is explained by the shift to computer-based forms of leisure use. In other words, the expansion of access to new technologies for leisure time entertainment resulted in young low-educated American men working between 75 and 150 hours less on average per year. Similar data are reported on average per year. Similar data are reported for other demographic groups. These trends are also confirmed in many other countries. From the above, it can be concluded **that more serious economic and social policy challenges are present in relation to supply rather than demand.**

2. Technical progress and the professions

In recent years, many developments have been published in which the relationships between NTP and the demand for labor is viewed on a fundamentally new basis. In particular, through the prism of changes in the professional structure of employment. In a number of works, the nature of modern technical progress is determined on the basis of its influence on the demand for one or another group of labor, i.e. for one or another profession. By definition, the term “profession” refers to a certain set of labor functions imputed to the worker to perform in the production process.

Technical progress has always brought about changes in the economy. In terms of the labor market, they are associated with a change in the skill structure of the labor force. Jobs have different characteristics. Some of them offer low pay and others high pay. In addition, some jobs involve more physical effort and others involve the application of mental labor. Depending on these circumstances, jobs may also be perceived as attractive or unattractive. In different historical periods, the impact of NTP on labor markets has had specific dimensions. What they all have in common is that these are mainly changes in the structure of employment.

A number of studies since the early 1990s have focused on the mechanism by which the computer revolution and the spread of ICT have led to changes in the demand for works with different qualification. In its simplest form, two main groups of employed people could be identified: low- and high-skilled. The experience already accumulated in developed countries shows that modern ICTs are directly related to the process of accumulating human capital. This is because their implementation and use require skilled workers with the relevant education (Bessen J. 2018). This understanding leads to the conclusion that **the new ICTs are complementary with regard to highly skilled workers, but substitutes with regard to the low-skilled.**

This type of technological change can be defined as “technological progress for the benefit of a highly skilled workforce” (“Skill-Biased Technological Change (SBTC)”) (Card, D. J. E. DiNardo. 2002: 733 – 783). This characteristic of technological change implies a consistent increase in demand for highly skilled labor and a reduction in demand for low- and unskilled labor. The consequences of this process can be outlined in the following directions:

- ✚ Improving the structure of jobs;
- ✚ Increasing labor productivity and wages, both for low- and high-skilled workers;
- ✚ Increasing the pay gap between different groups of workers;
- ✚ Widening income inequality.

The concept of SBTC was first introduced in a paper by Katz and Murphy in 1992. It noted that during the 1970s and 1980s, the number of highly skilled workers in the United States increased by an average of 3% per year. For low-skilled workers, there was a steady trend of decreasing in both their number and their relative level of pay was reported (Katz L., K. Murphy 1992: 35 – 78). Similar results were obtained in a study of OECD countries at a later stage. Here, the results indicate that a decrease in relative pay for low-skilled workers is reported only in the Anglo-Saxon countries, but not in the other continental European countries included in the sample (Machin S., J. Van Reenen 1998: 1215 – 1244). The divergence in trends is primarily attributed to institutional differences in labor markets in individual countries. The most serious changes in favor of highly skilled professionals are noted for companies and sectors where computerization has penetrated the deepest.

When discussing the problem of differentiating the impact of ICT on jobs, it should be borne in mind that the professional duties of different jobs could vary considerably even for workers with the same degree of qualification. This feature is not taken into account in the SBTC concept. However, it is taken into as a starting point by proponents of an alternative concept, **Routine-Biased Technological Change (RBTC)** (Bock, S., I. Fontaine 2025: 195 – 251). It is based on a more detailed classification of jobs according to what tasks workers must perform within one or another profession. These tasks can be: physical or intellectual, routine or creative. For this purpose, these groups were introduced by type of occupation: non-routine physical, non-routine cognitive and routine (physical or cognitive activities).

The group of routine refers to work operations with preset, monotonous and repetitive actions. Such operations involve, on the one hand, the following of a strictly scheduled protocol. For this reason, they are easily submitted to coding and programming with the help of modern ICTs. On the other hand, routine work is particularly characteristics of professions located

in the middle levels of the qualification hierarchy. These are bank tellers, clerks, accountants, etc. at the same time, many professions that do not require specific qualifications are difficult to submit to computerization. They need quick reaction, skills to communicate with customers and partners, etc. to an even greater extent, they do not apply to codification and professions located at the high levels of the professional hierarchy (managers, executives, etc.) They require complex problem-solving skills, intuition, creativity, persuasion skills, etc. From the above, **it can be concluded that within the RBTC concept, modern technologies are complementary to highly skilled specialists, neutral – for low-skilled staff and substitutive – for a medium-skilled.**

Three important implications arise from the RBTC concept. The first relates to the fact that in the total mass of tasks faced by workers, a shift from routine to non-routine operations is expected, since the performance of the former is already assigned to machines. Empirical confirmation on the tendency to reduce the proportion of routine tasks has been obtained in studies conducted for the countries of the Anglo-Saxon world, for Europe and Japan (Autor D., Katz L., M. Kearney 2006: 189 – 194; Goos M., A. Manning 2007: 118 – 133; Goos M., Manning, A., A. Salomons 2009: 58 – 63; Ikenaga T., R. Kambayashi 2010).

The second consequence is related to an increase in the polarization in the employment structure. In the middle segment of the professional scale there is a decline while an increase is noted towards the pole segments. The latter are concentrated in both well-paid and low-paid jobs. These changes are characteristic of a large part of developed countries. According to analyses carried out for the period 1993-2006, the share of medium-skilled workers in Western European countries decreased by 8 percentage points (Goos M., Manning, A., A. Salomons 2009: 58 – 63). Moreover, the highest rate of growth in the segment of low-paid jobs is observed in countries with a flexible labor market, such as the United Kingdom.

Third consequence is that RBTC is accompanied by a polarization in the wage structure in the wage structure. This means that wage growth in the extreme segments of the job distribution scale will push up wages in the middle tiers. This makes sense, since as a consequence of the introduction of ICT, the proportion of workers with intermediate qualifications will decrease. Therefore, RBTC will cause a decrease in their wages. However, such a development should not be taken as preordained. After all, new technologies can also be complementary in terms of maintaining the employment of middle-skilled workers. This, in turn, would lead to an increase in their salaries (Autor D., D. Dorn 2013: 1553 – 1597). At the same time, middle-skilled works who have been laid off from their previous jobs can be distributed in different proportions into low-and high-skilled jobs in other

sectors. According to Acemoglu D., D. Autor 2011, middle-skilled workers will be more likely to move to jobs with higher average pay.

The trend towards polarization in the pay structure has been confirmed for labor markets in many other countries. Today, RBTC is used by many economists who study the relationship between technological changes and dynamics in the employment structure.

Here is the place to note that different technological advances do not have the same impact on different groups of occupations. If computerization becomes the cause of the removal from the labor force and the provision of many routine intellectual activities to machines, the robotization takes away a number of physical activities from humans. Thus, robotization, unlike computerization, cause a decline in demand for low-skilled labor and growth in a high-skilled labor force. But not to reduce the demand for middle-skilled workers, as the classical version of the RBTC concept suggests (Graetz G., G. Michaels 2015). In other words, the process of robotization should be expected to bring about improvements in the structure of employment, not their polarization.

From a review of the various concepts made so far, it can be concluded that **initially economists were primarily interested in what change in the structure of employment would bring about the achievements of NTP.** More recently, interests have been redirected to finding an answer to the question of **the change that would occur in the overall level of employment in the economy as a result in the structure of employment, brought about by new technologies.**

In this new direction of research, the most popular is the work of Frey C.V., A. Osborne, 2013. In it the authors forecast changes in occupation-based employment for the American economy over the next decade or two, and many different occupations will be at risk from automation. As of 2013, it was reported that about 47% of the employed in the United States were at risk of such risk.

Using their methodology, other authors reach equally worrying results: 35% for Finland (Pajarinen M., P. Rouvinen. 2014), 59% for Germany (Brzeski C., I. Burk 2015), between 45 and 60% for EU member states (Bowles J. 2014). Experts at PricewaterhouseCoupers offer more moderate projections. They estimate that between 2017 and 2030, occupations that are currently participated by 38% of workers in the United States will disappear under the influence of automation (Bailey R. 2017).

According to the World Bank, automation and digitalization will eliminate 57% of all existing jobs in OECD countries over the next two decades. (World Bank 2024)

The projections presented should be taken into account by the responsible institutions that implement countries' economic and social

policies. This requires greater clarity in the methodology by which they are obtained.

According to Frey and Osborne's forecasts, the world today faces a serious threat of technological unemployment. Under the influence of NTP, workers' knowledge and skills will age at such a rate that education and retraining systems will find it difficult to achieve the necessary level of adaptation. The problem of automation of production is already rapidly beginning to displace people not only from routine operations and activities, but also those that require creativity and purely human qualities. In this sense, technological unemployment threatens not only occupations in which the performance of tasks is not codified.

In general, Frey and Osborne distinguish three forms of human activity that would hardly be automated: *perception and manipulation; creativity and social intelligence*. For occupations in which the proportion of these forms is significant, human labor retains its primacy over technical achievement. These are, above all, activities related to generating new ideas, negotiating and so on. In practice, however, routine occupations and operations that are potentially automated predominate. This indicates that the assumptions of the RBTC concept presented above are significantly understated. In other words, the circle of those at risk of technological unemployment today is wider.

In their study, Frey and Osborne covered 702 occupational groups from the U.S. Department of Labor Handbook. From this pool, 70 occupations were sampled to represent the scale of the risk of automation over the next two decades. By applying statistical methods, estimates were made that were determined to be correlated with the remaining 632 occupations. Then, using data on the number of employed people practicing these occupations, the authors divided the workers into three groups according to the degree of risk of automation in the occupations. Their probability distribution scale is as follows: 0 to 30 % low, 30 to 70 % medium and more than 70% high. The first group is 33% of all people employed in the U.S economy as of 2010. In the second group, 20% and in the third 47%. Based on their assessment, the authors conclude that in the near term, occupations that are currently practiced by about half of the American workers should disappear. Another conclusion is that despite the RBTC's predictions of the polarization of employment, low-skilled workers face the greatest risk of automation.

According to Bessen, J., 2017, on the other hand, these estimates seem quite worrisome, but on the other hand, they are not entirely realistic. A few years after the Frey and Osborne study was presented, the statistical information reflecting the picture in the American economy shows something different. Of the 37 occupations, such as accountants, auditors, bank clerks,

couriers, etc. that were projected to disappear completely, not one was fully automated. Presenting the picture in a longer dynamic order, Bessen points out that of the nearly 300 occupations that existed in the United States in 1050, only one had disappeared due to automation by 2010. This is the profession of elevator operator. The need for it disappeared because the doors of modern elevators now open automatically.

Other similar examples can be found in scientific studies on the subject. With the advent of ATM's researchers who predict an explosion of technological unemployment predict that the profession of bank teller will disappear altogether. In fact, the data show that between 1990 and 2010 in the United States, their number has increased by 50 000. Another profession that should have already disappeared is the cashier. The reason for this is the introduction of automated self-service tellers. And here the statistics show that the number of people practicing this profession has increased substantially, from 2 million to 3.2 million in the period under review. Another profession, support staff at law firms, which Frey and Osborne identify as in danger of total extinction, show an inverse trend to their predictions. Practitioners in the U.S. increased by 85000 over the period studied. (Bailey R., 2017)

On the basis of the above, it can be said that Frey and Osborne's methodology has its drawbacks that make their forecasts less realistic. These shortcomings are addressed in the development of Arntz M. et al., 2016. The authors argue that the vast majority of professions today are too heterogeneous in terms of the operations and functions they perform. In this sense, automation will not cause the complete disappearance of many of these occupations, but rather will result in a change in the structure of tasks performed. Such changes are associated with a reduction in the time spent by the worker to perform certain routine functions, and an increase in non-routine ones. These circumstances are not taken into account in Frey and Osborne's methodology.

As Arntz M. et al. points out in an average estimate for 21 developed countries when moving from an analysis at the level of whole occupations to one at the level individual functions, the share of jobs at high risk of technological substitution over the next two decades is estimated at about 9%. By country, this figure varies from 7% for South Korea to 15% in Australia. For the U.S., it is also estimated at 9%, which is in stark contrast to the 47% predicted by Frey and Osborne. The lower estimate is due to the fact that, to one degree or another, all occupations in existence today involve forms of human activity, which Frey and Osborne define as "engineering bottlenecks" that are difficult to overcome by automation. As a result, it can be concluded that **the prospect of introducing new technology in professions to**

supersede manual labor entirely is not so great. Rather, individual functions and tasks would be automated.

In explaining the reasons for the variation in country-by-country data, Arntz M. et al. consider the following circumstances. First there is a minimal risk of a decline in employment due to automation of production in countries where the educational level of the workforce is high. At the same time, sharing the view of Frey and Osborne, workers with low rather than average qualifications face a higher risk. Second, the determinant of employment dynamics are the adopted forms of labor organization by country. For countries where labor organization is based on close interaction between workers, the opportunities for automation are greater. Third, an important factor is the depth of penetration technological changes into the economy of the respective country. The potential for automation is greater in countries with a lower degree of penetration of NTP achievements. As a result, the prospect of replacing workers with machines is significant. For countries that have already made significant technological advances, the replacement has already taken place at an early stage and the potential for a new wave is less.

From the studies by Arntz M. et al. and by Frey and Osborne, some more important conclusions can be drawn. First, there are subjective expert assessments at the base. Subjectivism is in relation to the research focus, which is aimed only at three, generalized groups of workers – low-, medium – and high-skilled. Second, both studies only discuss the technically feasible automation of one or another industry, but not its economic expediency. Depending on the relative cost of production factors, it may be disadvantageous for firms to introduce new technological solutions, especially when they could not recover the associated costs. Third, workers in obsolete occupations do not always become unemployed after automation. Some of them adapt to the new working conditions by acquiring new habits and skills corresponding to the implementation of new technologies. Fourthly, the implementation of new technological solutions in manufacturing could take a significant period of time from the moment of their emergence. This is due to the practical manifestation of economic, regulatory and ethical obstacles. For example, the implementation of NTP achievements require a workforce with a certain qualification to be able to operate them. When one is absent or severely insufficient, the process of innovation is seriously delayed. Regulations can also be a significant obstacle. The example of autonomous cars is illustrative in this regard. Obstacles of a similar nature can be related to ethical norms specific to the countries concerned. An example in this direction is the preference for the sick and elderly to be cared by humans rather than robots.

The listed obstacles to the introduction of new technologies are by no means exhaustive. Neither Arntz M. et. Al., nor Frey and Osborne, take into

account the operation of compensatory mechanisms for employment of a macroeconomic nature.

As made clear in the previous parts of the paper, the implementation of NTP achievements does not only cause the elimination of old professions. It also has the potential for the emergence of new professions where in the future people will find a “work heaven”. The future will show to what extent the two trends will correlate.

Conclusion

The problem of the development and implementation of new technologies has been preoccupying researches for the past two centuries. Their attention is directed above all to the possible substitution effect they have on the participation of people in the production processes. At the present stage, reducing the demand for labor due to the influence of new technologies is no longer just a theoretical possibility, but rather a real prospect. There are many examples of lost jobs and disappeared professions.

Today, the question of the impact of robotization and automation on human participation opportunities remains open because discussions between researchers with different opinions continue. Many of them are united around the view that a boom in technological unemployment is unlikely, even in the short term. Evidence from various developments suggests that the pace of technological progress is now slowing, with a continuation of this trend looming in the near future.

With the significance of a more serious problem, the researchers perceive the impact of NTP on the supply of labor. Technological changes have significantly greater effects on the structure of employment than on its overall number. This is due to the fact that the modern dimensions of TFP introduce changes not only in the nomenclature of occupations, but also in their functional content. Specifically, it concerns the transformation of routine tasks into non-routine tasks within existing types of occupations.

To a large extent, the predictions of proponents of the thesis about the inevitability of technological unemployment turn out to be unrealistic. The reason can be found in the methodological approach used to form them. They overlook one particularly significant fact that humanity has existed until now and will continue to live in conditions of resource scarcity. As Alchian and Allen note, in a world with scarce resources to meet human needs, the potential number of jobs will always be unlimited (Alchian A. A., W. R. Allen 1972). Under these conditions, many human needs remain unmet. By increasing productivity, the NTP frees up resources to meet a wider range of needs, some of which would have been impossible in previous periods. In other words, the unmet needs of some people create the employment potential of others. This means that as long as there are unmet human needs, there will

be no shortage of jobs. Therefore, some researchers concluded that a complete replacement of human needs are fully met. As one of the fathers of economic science, A. Smith notes in “The Wealth of Nations” (Smith, A. 2006), which depends on the size of the human stomach, then the desire for variety knows no bounds.

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