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The Impact of Machine Learning on Labor Markets in EU Countries in the Context of Accelerating the Implementation of Artificial Intelligence

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ABSTRACT:
The progress of the development of artificial intelligence (AI) has led to its extensive implementation in various branches of activity. Artificial intelligence is also actively taking place on labor markets. We set out to analyze how machine learning (ML) technologies influence the structure and dynamics of economic systems, especially the labor market in EU countries. In the article we focused on the development of the implementation of artificial intelligence and machine learning, on changes in the labor market and the transformations of jobs. Artificial intelligence will lead to the disappearance of some jobs, but to the creation of new opportunities in emerging areas. Changes are occurring in the development of new skills, the adjustment of the educational system to meet the demands of labor markets influenced by AI. Problems of inequalities with social, economic, financial and educational impact will arise on the labor market. We discuss the development of strategies, proactive policies in supporting the transition of adaptation to technologies, retraining initiatives, supporting social groups and affected sectors. The challenges are significant, but the innovation brought by machine learning will contribute to economic growth, improving the quality of life, with proper management.

Keywords: machine learning, artificial intelligence, labor markets, transformations of jobs, educational system

1. Introduction

In recent decades, technological advances, including artificial intelligence and cutting-edge innovations in biotechnology and natural sciences, have revolutionized contemporary society and profoundly changed the way global economies operate. Among the most significant developments is the rapid development of artificial intelligence (AI) and machine learning (ML) technologies which are beginning to profoundly influence labor markets around the world. The European Union has not been left behind. This technological revolution has not only redefined production processes and service delivery, but also influenced the way employees interact with technology, generating both unprecedented opportunities and challenges (Ladaru et al., 2022). These moments are very important both for the development of the labor market and for each employee taken outside. On the other hand, the introduction of artificial intelligence and machine learning offers new opportunities to generate new jobs in emerging areas such as data analysis,

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software development, intelligent systems management, etc. important new directions (Radulescu et al., 2021). On the other hand, these technologies can lead to the automation of certain functions, which endanger traditional social jobs, with a deep focus on economic and economic inequalities. In this way, it is essential to understand how the structure of the labor market will transform and what skills are needed to face these challenges. How can we support this radical transformation process that is already underway. In this paper, we will explore the impact of machine learning on labor markets in European Union countries, analyzing the evolution of the implementation of these technologies and how they influence the dynamics of jobs (Ciobanu et al., 2019). We will also focus on the need to adapt the education system to emerging market requirements, emphasizing the importance of developing proactive strategies that support the transition to a skilled and adaptable workforce. Finally, we will see the necessary measures to mitigate the negative effects of these transformations, ensuring that the innovation brought by AI and ML contributes to economic growth and the quality of life. In a constantly changing world, addressing these challenges becomes an imperative for the sustainable future of European economies.

2. Artificial intelligence technologies

Eurostat statistical analyses on the use of artificial intelligence technologies by EU enterprises reflect rapid development, with benefits (in safer, cleaner transport, efficient production, cheaper sustainable energy, good decision-making. In 2024, 13.48% of EU companies used artificial intelligence (AI) technologies. The share of large enterprises was 41.17%. The use of AI was predominant in the information and communications sector. We observe that in 2024, the use of AI technologies increased by 5.45 percentage points compared to 2023, with a higher degree of adoption among large enterprises compared to SMEs. Thus, in 2024, 11.21% of small enterprises, 20.97% of medium-sized enterprises and 41.17% of large enterprises implemented Artificial Intelligence. This situation is due to the complexity of implementing AI technologies within companies, as well as the associated economies of scale and costs. In addition, 13.48% of enterprises in the EU with 10 or more employees were registered users of at least one AI technology (1. written language analysis; 2. conversion of spoken language. into speech recognition format). Technologies for identifying objects and people based on image recognition, machine learning for analyzing information and data are important. Technologies for automating robotic processes based on AI software are very appreciated by companies. In 2024, the proportion of companies using AI ranges between 3.07% and 27.58%, with Denmark having the highest share, at 27.58%, respectively Sweden (25.09%), Belgium (24.71%). The lowest results are in Bulgaria (6.47%). Poland (5.9%), Romania (3.07%). Compared to 2023, in 2024, the EU member states reported significant shares of enterprises that implemented AI technologies. Sweden recorded the highest share of 14.72 percentage points, and Portugal the lowest share of 0.77 percentage points. In the same year, the information and communications sector highlighted a 48.72% use of AI technologies, followed by the professional, scientific and technical services sector with a 30.53% share of companies that implemented the respective solutions.

Table 1. Artificial intelligence by size class of enterprise

Percentage of enterprises	**2021**	**2023**	**2024**
European Union - 27 countries (from 2020)	7.65	8.03	13.48
Euro area (EA11-1999, EA12-2001, EA13-2007, EA15-2008, EA16-2009, EA17-2011, EA18-2014, EA19-2015, EA20-2023)	8.36	8.81	14.39
Belgium	10.32	13.81	24.71
Bulgaria	3.29	3.62	6.47
Czechia	4.46	5.90	11.26
Denmark	23.89	15.17	27.58
Germany	10.56	11.55	19.75
Estonia	2.77	5.19	13.89
Ireland	7.88	8.01	14.90
Greece	2.61	3.98	9.81
Spain	7.67	9.18	11.31
France	6.67	5.88	9.91
Croatia	8.74	7.89	11.76
Italy	6.17	5.05	8.20
Cyprus	2.59	4.67	7.90
Latvia	3.72	4.53	8.83
Lithuania	4.45	4.86	8.76
Luxembourg	13.00	14.45	23.73
Hungary	2.98	3.68	7.41
Malta	10.16	13.17	17.30
Netherlands	13.10	13.37	23.06
Austria	8.83	10.79	20.27
Poland	2.86	3.67	5.90
Portugal	7.20	7.86	8.63
Romania	1.38	1.51	3.07
Slovenia	11.73	11.37	20.89
Slovakia	5.19	7.04	10.78
Finland	15.79	15.10	24.37
Sweden	9.92	10.37	25.09
Norway	10.82	9.17	20.77
Bosnia and Herzegovina	2.07	5.34	6.36
Montenegro	3.34	5.61	7.91
Serbia	0.90	1.82	6.95
Türkiye	2.69	5.51	4.42

Source: *https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Use_of_artificial_intelligence_in_enterprises*

The other types of economic activities recorded shares below 16%, with variations from 15.45% in the real estate sector to 6.09% in accommodation activities and construction. In 2024, 6.88% of companies implemented artificial intelligence technologies for analyzing text (text mining). We note that 5.41% of them adopted artificial intelligence solutions capable of generating written or spoken language (natural language). Companies used technologies for converting speech into a machine-readable format (speech recognition). AI technologies, which automate various workflows, support decision-making processes, identify objects and people, through image analysis (image recognition and processing), were used by 4.78% and 3.23% of enterprises, respectively. In contrast, AI technologies for analyzing written language are the most used, with a share of 21.44%, followed by machine learning for data analysis, with a share of 20.58%. AI technologies for automating various activity processes and supporting the decision-making process, recorded a share of 20.40%. In contrast, less used technologies, which facilitate the physical movement of vehicles with autonomous decisions based on environmental analysis, represent a share of 7.19%. The information and communications sector with a share of 30.11% had the highest proportion of enterprises using artificial intelligence in the field of text mining, and 25.83% in natural language generation, 25.66% in machine learning for data analysis. In the field of professional, scientific and technical services, text mining was the most frequently used artificial intelligence technology, with a share of 15.61% of all enterprises. This was followed by speech recognition, with 12.49%, and natural language generation, which registered 11.51%. As for the other activities implementing specific AI technologies, the share of enterprises ranged from less than 1% to 8.06%.

Cybersecurity is one of the biggest challenges for all EU Member States. The number and diversity of connected devices is expected to increase significantly in the coming years. Cyberattacks are a matter of public interest, having a significant impact not only on the EU economy but also on the activities of economic agents.

Table 2. Security policy, measures, risks and staff awareness by size class of enterprise

	2022	**2024**
EU 27 countries (from 2020)	91.84	92.76
Belgium	95.80	96.12
Bulgaria	81.88	83.23
Czechia	91.87	92.08
Denmark	98.19	97.53
Germany	96.32	96.50
Estonia	85.78	90.85
Ireland	91.54	86.22
Greece	75.34	71.84
Spain	87.65	89.92
France	93.39	93.20
Croatia	84.80	88.27
Italy	92.15	92.92

Cyprus	91.21	96.35
Latvia	82.66	88.88
Lithuania	88.13	90.92
Luxembourg	86.16	86.80
Hungary	78.95	84.75
Malta	93.14	93.91
Netherlands	95.56	95.75
Austria	92.49	95.38
Poland	93.33	94.11
Portugal	89.76	95.62
Romania	86.47	91.67
Slovenia	86.68	86.12
Slovakia	86.15	87.13
Finland	98.16	98.74
Sweden	90.67	92.65

source: Eurostat

Here are some ways these technologies are impacting cybersecurity: threat detection, incident response, behavioral analytics, threat prediction, improved authentication, automation of security tasks, vulnerability identification, user training and awareness.

3. Research methodology

In this paper, we set out to define the objectives, data collection methods, analysis tools, and how to interpret the results: 1. The research objectives are oriented towards identifying the impact of ML technologies on the structure of the labor market: analyzing how ML affects existing jobs and creates new opportunities. Analysis of transformations and adapting to new market requirements can be carried out by acquiring modern professional competencies needed in the labor market, including by investigating changes in skills and abilities requirements generated by the implementation of artificial intelligence and machine learning.

3.1. Examining social and economic inequalities. Examining the effects that the adoption of machine learning (ML) technologies can generate on existing inequalities in the labor market allows the implementation of new ML and AI technologies with significant transformational potential. The impact of these technologies can be analyzed from several perspectives: a. Disappearance of jobs. The automation of processes through ML can lead to the elimination of certain jobs, especially in sectors involving repetitive tasks and routines. This can disproportionately affect low-skilled workers, who are more vulnerable to job losses. This trend can exacerbate social and economic inequalities between those who have access to advanced education and training and those who do not. b. Creating new jobs. On the other hand, the adoption of AI and ML can generate new job opportunities in emerging fields such as software development, data analytics and IT services. These jobs usually require advanced technical skills, which can lead to a

polarization of the labor market: those who can adapt and learn these skills will thrive, while others may be left behind. c. Access to education and training. Unequal access to education and training is a key factor in perpetuating inequalities. Regions or communities that lack the resources to provide training in digital skills can suffer from an exacerbation of economic imbalances. This underlines the importance of initiatives aimed at ensuring quality education for all, regardless of socio-economic background. d. Impact on wages. The adoption of ML can also influence wages, contributing to the widening of wage disparities. Workers in fields with high demand for advanced technical skills may benefit from higher wages, while those in sectors affected by automation may experience decreases in income.

3.2. Proposed policies and strategies: Suggestions for proactive policies and reskilling initiatives. To address the inequalities generated by the adoption of AI and ML, it is essential to implement proactive policies and reskilling initiatives.
a. Retraining and vocational training programs. Continuing education initiatives: Implement accessible reskilling programs for workers affected by automation, focusing on digital and technical skills. Public-private collaborations: Create partnerships between educational institutions, companies, and governments to develop curricula that meet the needs of the labor market.
b. Accessibility and inclusion. Reducing economic barriers: Providing scholarships and grants for people from disadvantaged backgrounds who want to participate in technology training. Access to technology: Ensuring access to the internet and technology equipment for all communities, to facilitate online learning and vocational training.
c. Labor protection policies. Social protection measures: Implementing policies to support workers affected by job losses, such as unemployment benefits and support programs for professional retraining. Automation regulations: Creating legal frameworks to regulate the impact of automation on jobs and protecting workers' rights. d. Education and awareness. Awareness campaigns: Informing the public about the importance of digital skills and adaptability in the face of technological change. STEM education: Promoting science, technology, engineering and mathematics (STEM) education among young people, with a focus on the inclusion of underrepresented groups. By implementing these policies and strategies, society can address the social and economic inequalities generated by the implementation of artificial intelligence and machine learning, to guarantee a more equitable future in the labor market.

4. Bibliographic study

The authors Brekelmans, S. and Petropoulos, G. (2020) analyze the nature and geography of occupational changes in 24 EU member states between 2002 - 2006, investigating how the structure of the workforce is influenced by new technologies, such as artificial intelligence and machine learning. The authors Tiwari, R. (2023) investigated the potential impact of the use of artificial intelligence and machine learning on the labor market, analyzing how the respective AI technologies could lead to the replacement of certain jobs and the creation of new employment opportunities in various fields. The ways in which technologies can lead to job replacement in certain cases, industries and the

potential for new employment opportunities in other fields were analyzed. Authors Lane, M., Martin, A.M., (2021) created new fears about the large-scale loss of jobs due to the automation of fast-paced tasks, the potential to affect every sector of the economy. The idea persists that AI will threaten and eliminate many jobs. AI has the potential to complement and enhance human capabilities, lead to higher productivity, higher demand for human resources, improved quality of jobs. The authors Boselli, R., at all (2017) argue that the rapid growth of the use of the Web for job promotion, offers excellent opportunities for real-time monitoring of the labor market, is the purpose of LMI - a relevant field in the future, for the design and evaluation of EU labor market policies. Leal Filho, W., at all (2023) argue that industrialized countries are beneficiaries of the emergence of 21st recent advances in natural language processing (NLP) allow the design of new measures of employee exposure to artificial intelligence (AI) and machine learning (ML) technologies in the period 2010-2023, with variations depending on the company and the time analyzed. Laukes, M.M. (2024) argues that the effects of technology on employment are increasingly evident, especially in terms of the required skills. The authors examined both the effects of using artificial intelligence on the labor market and the influence it may have on the skills and abilities required for the fields of AI and ML. Authors D. Autor and A. Salomons (2018) argue that many technological innovations lead to the replacement of certain jobs. However, this replacement of labor by capital should not reduce aggregate labor demand, as it simultaneously generates production effects in the respective sector; input-output effects between sectors; transfers between sectors; impact on final demand. In the analysis of automation, variations in total factor productivity (TFP) were assessed at the industry level, a common aspect across countries.

5. The impact of machine learning on labor market development

5.1. Machine Learning and Its Influence on Workforce Evolution

In the context of the development of artificial intelligence is a complex and multidimensional topic, with profound implications for the way we work and interact with technology. We identify several aspects for discussion: (1) Job automation, in which machine learning allows the automation of well-defined, repetitive tasks, with a reduction in the number of jobs in certain sectors. For example, the manufacturing, transportation, and customer service industries are already affected by automation, which can lead to job losses for unskilled workers. Vermeulen, B., Kesselhut, J., Pyka, A. and Saviotti, PP (2018) studied the projected impact of automation on employment at both the macro and sectoral levels is analyzed by combining an evolutionary economic model that examines structural changes in multiple sectors with economic labor theory. Wajcman, J. (2017) reviews several recent sources that deal with the impact of automation and robotics on the future of jobs. Most experts estimate that, in the current context of digital technology, this wave of automation, which generates significant job losses, is different from previous waves. Digital technology now has the capacity to automate professions for the first time. The author Badet, J. (2021), in his paper on AI automation and the impact on jobs, examines the benefits that automation brings to the professional field. Although a significant number of jobs are replaced by automation, it generates new opportunities for the creation of new jobs, with more complex tasks. The authors turn their attention to the skill level required to capitalize on these new opportunities. By analyzing the results of the model,

the development of new tasks, in which the workforce has a comparative advantage, is highlighted and represents beneficial aspects of the automation process. Authors Arntz, M., Gregory, T. and Zierahn, U. (2016) state that there has been a revival of interest in the issues of automation and digitalization, which could lead to a future without jobs. This analysis is based on studies from the US and Europe, which claim that "a significant part of jobs is exposed to the risk of computerization". The studies adopt the occupation-oriented approach proposed by Frey and Osborne (2013), suggesting that the entire occupation of the workforce can be subjected to the process of automation, not just certain individual tasks.

5. 2. Job Automation in the Context of Machine Learning and the Development of Artificial Intelligence (AI).

The forced automation of jobs is a complex and relevant issue for the economies of the European Union (EU). This transformation is influenced by several factors, including technological advances, labor market demands, and government policies. We highlight some important aspects: (1) Impact on jobs with job displacement: Automation can lead to the elimination of certain jobs, especially in sectors such as manufacturing, transportation, and administrative services. Repetitive or predictable functions are the most vulnerable. (2) Creation of new jobs. While some jobs disappear, others appear, typically in the fields of software development, automated systems development, and data analysis. It is essential that the workforce adapts to the new requirements. (3) The need to train and retrain the workforce, through education and vocational training. Preparing employees for the transition to jobs that require digital skills through reskilling and continuous training initiatives is becoming increasingly important. Through collaboration between the public and private sectors. Partnerships between governments, educational institutions, companies can facilitate the development of training programs tailored to market needs. The authors Baumann, N., Kusmenko, E., Ritz, J., Rumpe, B. and Weber, MB (2022), studied the management of dynamic datasets that can serve as input for a machine learning (ML) model and it appears to be very difficult, when the data is iteratively modified and existing ML models should refer to the data. Model-based concepts and implementation, designed for the complexity of iterative data management, as a facilitator in the integration of continuous retraining routines. Deep learning techniques, which have become feasible ethnically, developed as a priority in the last decade (MLOps - aims to establish DevOps adapted to ML projects, has great relevance).

5.3. Public policies and regulations

By promoting active employment policies, EU member state governments must develop policies that support employees affected by automation, including through social protection measures and incentives for retraining. Technology regulation is necessary. Legislation should keep pace with technological innovations, ensuring that the use of AI and automation is done in an ethical and responsible way. Employment policies and technology regulation are essential to face the challenges generated by automation and artificial intelligence (AI). For example, we present some concrete measures that could be implemented in these areas: (1) Retraining and vocational training programs. Governments should develop and finance programs that help employees develop new skills, especially

in areas of high demand, such as information technology, health or sustainability. (2) Social protection measures, by implementing unemployment insurance schemes, with better financial support offers for employees affected by automation, with access to career counseling services. (3) Creating incentives for employers by offering subsidies, tax deductions for companies that invest in employee training, which create new jobs in emerging areas. (4) Developing and promoting entrepreneurship, by creating programs that encourage entrepreneurship, innovation, offering grants, microfinancing, support in developing business plans for those who want to launch their own businesses. (5) It is necessary to regulate technology through the following measures: Creating an adaptable legislative framework, by developing flexible legislation, quickly updated according to technological advances, ensuring the protection of employee and consumer rights. (6) Setting ethical standards for artificial intelligence involves formulating clear rules on its use, the transparency of algorithms, accountability for automated decisions and the protection of personal data. It is essential that agencies oversee automation and artificial intelligence technologies, ensuring that they are not used in ways that could harm jobs or society.

Conclusion

The integration of machine learning (ML) and artificial intelligence (AI) into the labor markets of the European Union (EU) countries is a transformative phenomenon that brings both opportunities and challenges. As demonstrated by the rapid adoption of AI technologies in various sectors, especially in information and communications, we are witnessing important changes taking place in European labor markets, both in developed and transitioning countries, and by the notable existence of mu in job dynamics. While ML has the potential to increase productivity and create new categories of jobs in technology-based fields such as data analysis and software development, it simultaneously threatens to replace traditional jobs, especially those involving repetitive tasks in manufacturing, transportation and customer service. The integration of machine learning (ML) and artificial intelligence (AI) into labor markets in European Union (EU) countries is a transformative phenomenon that brings both new opportunities and challenges.

As demonstrated by the rapid adoption of AI technologies in various sectors, especially in information and communications, we are witnessing important changes taking place in European labor markets, both in developed and transition countries, as well as by the notable existence of mu in job dynamics.

While ML has the potential to increase productivity and create new categories of jobs in technology-based fields such as data analysis and software development, it simultaneously threatens to replace traditional jobs, especially those involving repetitive tasks in manufacturing, transportation, services and other customer-facing activities.

The implications of these changes are multiple. First, the automation of jobs could exacerbate existing social and economic inequalities, disproportionately affecting low-skilled workers and those without access to advanced education. This polarization of the labor market requires significant reassessment of the skills needed for future jobs, underlining the urgency of adaptation in education systems. Furthermore, differences in AI adoption rates across EU countries reflect a growing divide that could hinder overall

economic cohesion within the Union. The challenges posed by ML and AI are compounded by the need for strategic public policies that not only facilitate the transition of workers affected by automation but also promote equitable access to the necessary skills and training. Without proactive measures, innovations brought about by AI may lead to a growing gap between those who can adapt to new technologies and those who cannot, ultimately undermining the social fabric of the EU. Recommendations Invest in reskilling and training: Governments should priorities funding and develop accessible reskilling programs that focus on digital and technical skills. Collaborations between educational institutions, businesses and public authorities are essential to create curricula aligned with current labor market demands. Improving access to education: Initiatives aimed at reducing economic barriers to education are crucial. This includes providing scholarships, grants and ensuring that technology and internet access are available to all communities, especially in disadvantaged regions. Strengthening social protection policies: Implementing robust unemployment insurance schemes and career counselling services can support workers displaced by automation, ensuring they have a safety net as they transition to new roles. Incentivizing business investment in training: Governments should offer subsidies or tax breaks to companies that invest in employee training programs, especially in sectors that are expected to grow due to advances in AI. Promoting entrepreneurship and innovation: Creating programs that encourage entrepreneurship can help mitigate job losses by encouraging people to start their own businesses. Providing support, such as microfinance and business plan development, can empower workers to take control of their economic future. Setting ethical standards for AI: A regulatory framework that ensures the ethical use of AI technologies is vital. This includes transparency in algorithmic decision-making and accountability for automated processes to protect consumer rights and labor standards. Cross-sectoral collaboration: Encouraging partnerships between governments, the private sector, and non-governmental organizations can lead to more effective policies that address the multiple effects of automation on labor markets. Continuous monitoring and adaptation: Establishing dedicated bodies to oversee the implementation and impact of AI and ML technologies can ensure that their implementation does not negatively affect employment or societal well-being. This oversight should include mechanisms to adapt regulations in response to technological advances. By implementing these strategies, the EU can harness the potential of machine learning and artificial intelligence to boost economic growth while ensuring a fairer labor market. It is imperative that all stakeholders - governments, businesses and educational institutions - work together to navigate the complex landscape of technological change, facilitating a transition that benefits all members of society.

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