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**Navigating Worker Displacement in the Age of Automation: The
Future of Work**

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Table of contents:

ABSTRAT	4
INTRODUCTION	5
CHAPTER 1 Background: The historical trend of automation and its increasing pace	8
CHAPTER 2 Understanding Worker Substitutability	14
2.1 Factors affecting workers Substitutability.....	16
2.2 Perfect Substitutability and Complementarity vs Imperfect Substitutability and Complementarity	20
2.3 The Modern Manufacturing Landscape: Efficiency and Adaptability.....	32
2.4 Methods for measuring substitutability.....	34
CHAPTER 3. The Rise of New Technologies and Worker Replacement	47
3.1 Artificial Intelligence: the rise of AI and its potential to automate tasks.....	50
3.2 Automation and Robotics: advancements in automation and robotics and their potential impact on job categories.....	66
CHAPTER 4. Italian situation and positioning	75
4.1 Italian robotics.....	77
4.2 Italian Artificial Intelligence	83
4.3 Workers displacement in Italy.....	85
CHAPTER 5 Incentives to maintain workers in companies rather than replacing them	95
5.1 Italy’s Approach to workforce Retention and Upskilling	99
CONCLUSION	103
BIBLIOGRAPHY.....	105

ABSTRAT

This thesis investigates worker substitutability in labor economics, focusing on the effects of technological advancements such as automation and artificial intelligence (AI) on the labor market. Worker substitutability refers to how easily one worker can be replaced by another without impacting productivity. The study explores how automation pressures wages, reduces bargaining power, and increases the risk of job displacement, particularly for workers in low-skill and routine roles.

Analyzing automation trends and AI integration, the research highlights the differing vulnerability of job types to technological disruption. While tasks that are repetitive and easily automated face greater risk, jobs requiring creativity, problem-solving, and interpersonal skills are less affected. The role of unions and retraining programs is examined as a way to mitigate automation's impact by preserving jobs and supporting transitions into new roles.

Using Italy as a case study, the thesis explores how industries are adapting to automation. It also examines the country's policies aimed at retaining workers through reskilling and labor protections while staying competitive globally. The research concludes by emphasizing the importance of strategic workforce planning to ensure technological progress benefits society and minimizes harm to workers.

INTRODUCTION

The evolution of automation represents one of the most transformative developments in human history, spanning from the earliest labour-saving innovations to the sophisticated technologies of the present day. Automation, which has its roots in the innate human desire to increase productivity and lessen physical strain, has shaped economies, industries, and communities all over generations. Early mechanical advancements, such as the invention of the wheel and lever laid the foundation for more efficient labour and manufacturing techniques. Even though these simple instruments are ancient by today's standards, they signalled the start of humankind's quest to reduce manual labour and maximise the use of resources and energy.

An enormous change in automation was brought by the first Industrial Revolution (18th century), which also marked the beginning of the mechanisation era with important inventions like the steam engine, standardised parts, and others. This period not only revolutionized industries, but also redefined the nature of labor, as human tasks became increasingly supplemented or replaced by machines. In the 20th century, the automation landscape was radically altered with the introduction of the assembly line, industrial robotics, and the digital revolution powered by computers. These advancements enabled mass production at unprecedented scales, transforming all industries.

The concept of worker substitutability is becoming increasingly relevant as automation and technological advancements have reshaped the global workforce in the last decade. Worker substitutability, as used in labour economics, describes how easily one worker may be replaced by another without compromising output. This concept has far-

reaching implications for wage dynamics, unionization, and the impact of technology on employment. Navigating the intricate interaction between labour and technology, particularly in industries where automation is quickly developing, requires an understanding of worker substitutability. We are currently at the point of another major automation breakthrough, propelled by cutting-edge technologies like robotics and artificial intelligence (AI). These innovations present both opportunities and challenges for the modern workforce. While AI and robotics have the potential to further enhance productivity and foster economic growth, they also raise important questions about the future of labor. The substitutability of workers especially in employment that require repetitive or easily replicated tasks becomes an increasingly important factor in labour economics as automation technologies improve and become more widespread and advanced. Automation has the potential to worsen economic inequality, if not utilized in the correct way. For this reason, careful governmental interventions, strategic workforce planning, and a continuous emphasis on education and reskilling are essential.

When considering labour substitutability in the context of growing automation, Italy provides an insightful case study. In recent years, Italy has experienced significant growth in adopting new technologies, accelerating its embrace of automation and digital transformation across various sectors. This paper explores the dynamics of worker substitutability and automation, highlighting Italy's approach to balancing technological advancement with the preservation of human labor made. Italian businesses and policymakers have prioritized worker retention, emphasizing on different procedures to maintain an high level of human labor inside firms. This essay examines the dynamics of automation and worker substitutability, emphasizing Italy's strategy for striking a balance between the growth of technology and the need to preserve human labour. By

analyzing historical trends, current developments, and future projections, this research aims to provide a comprehensive understanding of the implications of automation on worker substitutability, while also addressing broader socio-economic impacts and proposing potential policy solutions for an equitable transition to a more automated future.

CHAPTER 1. Background: The historical trend of automation and its increasing pace.

Although automation is frequently connected to contemporary robots and machines, its historical roots are far deeper. There is evidence to imply that humans have been searching for labor-saving techniques since the dawn of civilization. This chapter examines the first examples of automation via the perspective of important technologies like the wheel, the plough, and the lever.

The invention of the wheel, estimated to have occurred around 3000 BC, stands as a seminal example. Prior to this innovation, transportation of goods relied heavily on human or animal muscle, resulting in significant exertion. The introduction of the wheel revolutionized this process, enabling the movement of heavier loads with considerably less effort. The wheel's impact extended beyond mere transportation, influencing advancements in woodworking and other craft disciplines (Noël, 1988)

The plough also came to be recognized as an example of early automation. Compared to hand tilling, this agricultural instrument boosted the effectiveness of land cultivation by utilizing horsepower. This invention clearly lessened the physical strain on farmers, enabling them to cultivate bigger areas more easily. Also, the lever is an additional example of the early human drive to increase physical skills. It is an apparently simple item. Through the use of the fulcrum and leverage concept, people were able to lift or move items that would have been difficult to do with only pure force. This technique proven to be quite useful in a variety of applications, including combat and building (Channell, 2009)

Despite its relatively insignificant wooden design, the plough is a potent reminder of humanity's early attempts at mechanization. Its appearance, which is thought to have happened in Mesopotamia about 6000 BC, signaled a significant change in farming methods. Agriculture relied mostly on manual labor until the invention of the plough, which was labor-intensive and produced little. But the invention of the plough transformed the preparation of land. Farmers were able to cultivate greater land with a great deal less physical effort by using the power of tamed animals like horses or oxen. This invention had a significant influence on how human cultures evolved. Larger populations may be sustained thanks to an increase in agricultural productivity brought about by the plough's enhanced efficiency. Consequently, this promoted the growth of early civilizations, the construction of permanent settlements, and the formation of social hierarchies. (Cohen,1977)

The plough had an effect that went beyond just producing food. A greater supply of agricultural surpluses made labor more specialized, which in turn promoted the growth of commerce, crafts, and eventually complex economies. Furthermore, the plough strengthened the bond between humans and animals by promoting improvements in animal husbandry and breeding due to its reliance on animal power. (Bellwood, 2024)

The plough evolved through an evolutionary process rather than as a single occurrence. Simple digging sticks were probably the first versions, and then hard-type tools that scraped the dirt surface were introduced. (Adil El Mane, 2024)

While the wheel and the plough represent undeniable advancements in early automation, the seemingly simple lever deserves no less recognition. Its invention

stands as a testament to the ingenuity of our ancestors and their relentless pursuit of methods to lessen physical exertion (Noël, 1988).

The lever, a seemingly simple tool, further exemplifies the early human desire to augment physical capabilities. By utilizing the principle of fulcrum and leverage, individuals could lift or move objects that would otherwise be impossible with brute force alone. This technology proved invaluable across various applications, from construction to warfare. (Oosterlaken, 2015)

The Industrial Revolution, a pivotal time in human history, occurred in the 18th and 19th centuries. This was not just an age of higher output and economic expansion; it also represented a significant shift in the direction of automation. Even if they were clever, the potential of equipment and procedures to replace human labor on a wide scale was severely constrained until this time. A wave of mechanization was brought about by the Industrial Revolution when machines took the place of human labor in many manufacturing processes (Groumpos, 2021).

This radical shift resulted from a combination of important discoveries. One of the greatest achievements ever is the discovery of the steam engine. Before then, a large portion of production was dependent on water mills, which had erratic power output and were restricted in terms of geography. On the other hand, the steam engine provided a stable and reliable energy supply that allowed manufacturers to run continuously, without reliance on natural water supplies. The growth of factories, the centralized centers of industrial activity, was powered by this steady supply of electricity. (Vries, 2008) In addition, Eli Whitney developed the revolutionary idea of replaceable components in the late 1700s. This straightforward concept transformed the industrial

industry. Before, every part of a product was made by hand, which caused irregularities and hampered mass manufacturing. Whitney's idea standardized parts so that similar parts could be produced and easily put together. Due to the ability to build machines that could handle standardized components effectively and streamline production lines, this discovery led to a considerable increase in automation.

Perhaps the most vivid illustration of this transformation can be found in the textile industry. The sector, once reliant on manual labor for spinning and weaving, underwent a dramatic shift. Power looms, driven by steam engines, replaced the laborious process of weaving by hand. Similarly, spinning jennies, with their multiple spindles, vastly increased the efficiency of yarn production compared to traditional hand spinning. These innovations significantly reduced the requirement for manual labor in the textile industry, a stark demonstration of the power of automation during the Industrial Revolution.

The development and application of automation technologies saw a rapid increase in the 20th century. The earlier mechanization breakthroughs were expanded upon during this time, but a significant move towards a more complex and integrated strategy was made. When Henry Ford implemented his invention of the assembly line in the early 20th century to manufacture cars, it turned into a significant innovation. (Behzad Esmaeilian, 2016) claim that this method revolutionized mass manufacturing by breaking down complex tasks into smaller, more standardized procedures that were completed by labourers and specialist equipment. The assembly line significantly increased production and efficiency, laying the foundation for the modern manufacturing environment.

Later in the century, the development of industrial robots marked a major leap forward in automation. These programmable machines, with their superior accuracy and tireless operation, began to replace humans in performing monotonous and often dangerous tasks on factory floors (Carl Benedikt Frey, 2017). This shift not only improved safety but also allowed for greater precision and consistency in production.

The widespread use of computers in the middle of the 20th century led to an even greater increase in automation. Unlike their mechanical forebears, these formidable machines provided the capacity to automate intricate decision-making procedures that were previously exclusive to human labor. Computers made it easier to automate processes, from data processing to industrial control systems, as noted by Frey & Osborne (2017). This newly acquired skill greatly increased the automation's reach and affected many industries than only manufacturing.

the 20th century stands as a pivotal era in the history of automation. During this time, industrial robots and computers were introduced, and the assembly line was a game-changer. Automation technologies continued to advance and become more commonplace. These developments had a profound impact on how products were made, and services were provided, changing the social and economic fabric of the contemporary world.

The rate of automation has increased at an unprecedented rate in the twenty-first century. The three primary technology fields of robotics, machine learning, and artificial intelligence (AI) are seeing tremendous breakthroughs, which are the driving forces behind this phenomenon. Financial services, healthcare, and customer service are just a

few of the areas that are being impacted by the convergence of these fields to automate a larger variety of jobs than ever (James Manyka, 2017).

The exponential rise in computing power is one of the main causes. Moore's Law, which states that a microchip's transistor count doubles approximately every two years, is still valid. More sophisticated automation solutions can be developed because of this exponential expansion. Tasks like pattern recognition, decision-making, and complicated data analysis that were before thought to be limited to human intellect may now be handled by sophisticated algorithms driven by AI (Artificial Intelligence) and ML (Machine Learning). With this increased capacity, automation may now cover additional cognitive and analytical jobs in addition to repetitive ones.

The falling cost of automation technology is another important element to consider. The cost of sensors, robotics, and the computer power needed to power them has all dropped dramatically in recent years. Automation is now a feasible choice for businesses of all sizes, not only big enterprises with substantial financial resources, thanks to this cost reduction. Automation may now be used by smaller companies to increase productivity, save expenses, and obtain a competitive advantage (Michaels, Robots at Work The Review of Economics and Statistics, 2018).

CHAPTER 2. Understanding Worker Substitutability

Employees perform different tasks inside a complex organization as the firm is. These tasks are usually interrelated among them, and the performance of those who are employed in a particular task depends on the number of workers employed in the other task. Although, the number of employees performing different tasks within a firm is an important variable to the success of the firm, performance is highly influenced by the level of the productivity, time, talent of the personnel, effort put on a given job.

The specific type of product offered by the company in the market defines the types of tasks needed in the production process. Assuming that the different tasks directly define the skill of the workers, “skill” and “tasks” will be used through as interchangeable. A firm that needs different tasks in production will employ workers with different skills (Staffolani, 2022).

Supposing that workers tasks can be replaced by technology under the concept of worker substitutability, a cornerstone of labour economics, that revolves around the ease with which one worker can be replaced by another to achieve comparable outputs within a specific role. (David H. Autor, 2023)

Essentially, it demonstrates the ease by which labour can be replaced within a job function. This concept holds significant implications for wages, unionization, and the impact of technological advancements on the workforce.

The specter of automation looms large over the labour market, prompting researchers to delve into the concept of worker substitutability. One prominent approach, centers on **task automation potential**. This method, resembling to dissecting a machine, meticulously unpacks the constituent tasks that comprise a specific job. Researchers then meticulously assess the likelihood of automating each task with existing

technologies. “Occupations characterized by a high degree of automation potential – think the repetitive, rule-based tasks found on an assembly line – are deemed more substitutable” (Erik Brynjolfsson D. R., 2017).

detailed analysis of tasks within jobs allows businesses and policymakers to make a prevision on which roles are most vulnerable to automation. Routine transactions performed by bank tellers, for instance, can be more easily replaced by ATMs and online banking systems, but jobs requiring complex problem-solving and customer service may still need human labour. Additionally, worker substitutability has repercussions regarding more general economic and social problems. As automation potential increases, there may be downward pressure on wages for highly substitutable jobs due to the ease of replacing workers with technology. This dynamic could also influence unionization, as workers in less substitutable roles might possess greater bargaining power compared to those in easily automated positions (McKinsey&Company, 2017).

Through the perspective of job automation, worker substitutability offers important insights into how technology improvements might transform the labor market. It highlights the varying degrees of vulnerability across different occupations and underscores the need for strategic workforce planning and policy interventions to manage the transition toward a more automated economy. This comprehensive understanding can ensure that technological advancement benefits society as a whole and assists in minimizing potential negative impacts on the work-force.

2.1 Factors affecting workers Substitutability

Worker substitutability is a concept that addresses how easily one worker can be replaced by another while maintaining similar levels of productivity and efficiency within a specific role. This concept has become increasingly relevant in today's job market, characterized by rapid technological advancements that constantly reshape the landscape of work. These advancements are not only reshaping the nature of work but also influencing various aspects of the labor market, including wages, unionization, and job security.

wages, unionization, and the impact of technological advancements, these elements are the factors effecting substitutability in a more remarked way. Let's se these elements in a more in-depth way:

The relationship between worker substitutability and **wages** is a well-documented phenomenon in labor economics. Lower wages usually appear in jobs where employees may be easily replaced. The two main causes of this disparity are bargaining power and market supply:

- **Bargaining Power Disadvantage:** A worker's negotiating power decreases in pay negotiations when their talents are easily copied by others (Simon Jäger, 2022). Employers can credibly threaten to replace them with readily available candidates willing to work for less amount of wage. This dynamic is particularly relevant for positions requiring minimal training and having a large pool of potential hires. Fast-food employees, for example, deal with this issue. Their capacity to bargain for better pay is weakened by the number of prospective substitutes and the transferability of their abilities.

- **Market Supply and Wage Determination:** Worker substitutability often correlates with the size of the available labor pool. When there's a surplus of qualified workers for a particular role (high substitutability), wages tend to be lower due to increased competition among potential employees. On the other hand, because there are limited qualified applicants for specialised roles with low substitutability, these professions frequently attract greater salaries. For example, the pool of qualified substitutes is less for software developers because their abilities are difficult for others to imitate. This limited pool strengthens their bargaining position, leading to higher wages compared to readily replaceable workers in the fast-food industry.

A remarkable relationship between worker substitutability and collective bargaining power can be seen in the **unionization** landscape across numerous industries.

Sectors with limited worker substitutability are more likely to have higher unionization rates

This correlation is not coincidental (Staffolani, 2022), but rather a reflection of the strategic advantage such workers possess when negotiating for better wages and working conditions. Two key aspects contribute to this dynamic:

- **Sector Variability:** Union strength varies by sector. For example, skilled trades (e.g., electricians, plumbers) often have strong unions because their expertise is not easily replicable. Unions in highly substitutable industries, like retail, may find it more difficult to get employers to make comparable concessions. Furthermore, unions can help safeguard workers from automation-related job displacement by lobbying for retraining initiatives or tech adoption plans that reduce employment losses.

- Collective Bargaining Unions give employees in non-replaceable industries a collective voice. When it comes to technical breakthroughs that could lead to job displacement through automation, the collective voice becomes even more important (ANDRÉS AGUILERA, 2016). To reduce job losses, unions can actively advocate for retraining programs and sensible tech adoption strategies. Unions provide a safeguard against the adverse effects of automation by standing up for their members, which makes the workforce more flexible and safer.

Automation especially represents a bigger danger to jobs where worker substitutability is strong. Regular and rule-based tasks are easily automated, which may cause workers in those roles to lose their jobs (Erik Brynjolfsson D. R., 2017). The effect of technical improvements on worker substitutability is highlighted by three important factors:

- **Automation Potential:** Jobs with a lot of repetitive work have a higher chance of becoming automated. For example, data entry clerks and assembly line workers are more likely to be replaced by robots or software that can complete these duties more quickly and accurately.
- **Employment Impact:** There may be an important shift in employment once highly substitutable jobs are automated. To remain competitive in the labour marketplace, workers in these roles might have to consider options of changing careers or allocate resources on retraining.
- **Technological Displacement:** As technology develops, there may be a greater danger of automation for even jobs that were before thought to be less interchangeable. For instance, jobs that were previously thought to be secure from automation, including legal research and medical diagnostics, are starting to be automated as a result of

advances in robotics and Artificial Intelligence. Because people in low-paid, high-substitutability positions are more likely to lose their employment, and because high-skilled, low-substitutability roles may experience greater demand and salary premiums, this trend of technological displacement has the potential to worsen economic inequality.

2.2 Perfect Substitutability and Complementarity vs. Imperfect Substitutability and Complementarity

Understanding the dynamics of substitutability and complementarity among inputs is crucial when exploring the complexities of production and resource management. These concepts are not merely theoretical but they play a pivotal role in the modelling and optimization of workflows. Perfect substitutes and perfect complements are two extremes on the spectrum of how goods relate to each other in terms of consumer demand, they both play a significant role in the allocation of tasks, the management of resources, and the efficiency of organizational operation. It is essential to comprehend these dynamics for several reasons. It has a direct impact on how work is distributed and managed within a company. For instance, in a setting where inputs are complementary, meticulous planning is required to ensure that all necessary resources are available in the correct proportions (Jeroen B.H.C. Didden, 2023). This is essential to maintain efficiency and prevent production bottlenecks.

Understanding areas in which substitutability is possible may also reduce costs and provide flexibility. It allows for more adaptive resource management, which can be particularly valuable in fluctuating markets or when facing unexpected challenges. However, it is crucial to acknowledge the limitations of substitutability and complementarity to avoid overestimating the interchangeability of different inputs. Let's examine these concepts in greater detail.

Perfect substitutability describes a situation in which two or more inputs may be completely swapped out during the production process without affecting the result. This theoretical framework assumes a high level of worker skill fungibility and job

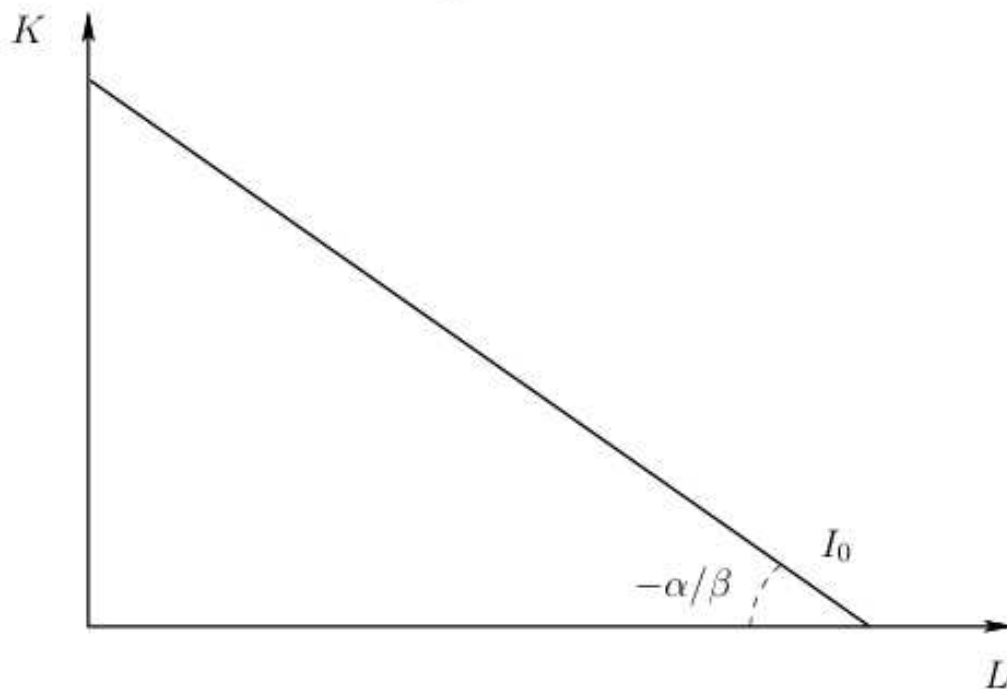
homogeneity. However, because of the inherent complexity of production processes in modern organisations, this is only a theoretical approach rarely achieved in practical implementation.

Perfect substitutability makes economic model analysis easier, but real-world production systems frequently show strong task interdependencies. There might be a network of interconnected tasks if the successful completion of one job depends on the success of another. Because of this interconnectedness, workers must focus coordinate and specialise on some tasks, making perfect substitutability unfeasible in most situations (Jean Mercier Ythier, 2006).

Many tasks within an organization require specialized skills sets and experience that cannot be readily replicated through simple worker substitution. For instance, the intricate decision-making required of surgeons cannot be easily replaced by surgical robots, even with advancements in technology (David H. Autor, 2023).

Effective teamwork hinges on collaboration, trust, and shared goals – elements that technology struggles to fully replicate. The ability to bounce ideas off each other, anticipate problems, and adapt to unforeseen circumstances are crucial aspects of human interaction that contribute significantly to overall productivity.

Graph 1 – Isoquants when inputs are Perfect substitute.



Source: Ecograph,

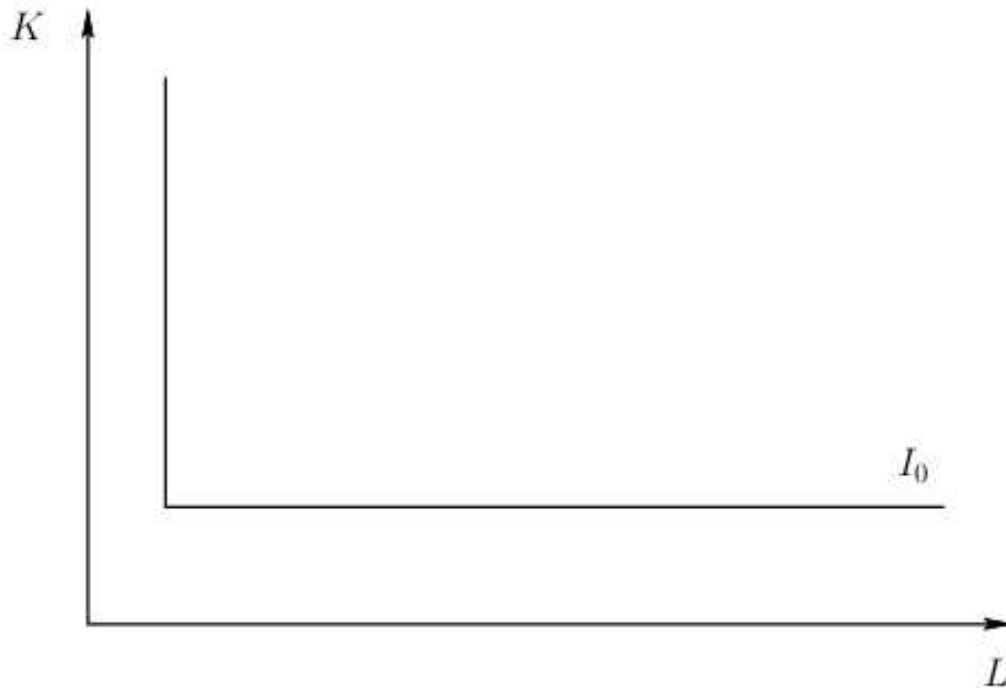
On the opposite end **Perfect complementarity**: presents a fascinating phenomenon in production processes. It describes a scenario where two or more inputs, often in the form of labor for specific tasks, become indispensable partners in achieving any positive output. This implies that employing one input without the other yields no output (Giulio, 2021). Similarly, perfect complements represent tasks that are intricately linked, requiring precise synchronization for any meaningful result. Let's examine the essential elements of perfect complementarity in more detail:

- **Fixed Ratio Requirement:** The two activities must be completed in a certain ratio (e.g., 2:1) for any output to be generated. Zero production occurs when workers are employed in a different ratio.
- **Isoquant Representation:** An output level that can be produced by a combination of inputs is represented by an isoquant in production theory. The isoquants for perfect complements reflect the fixed ratio requirement by taking the shape of right angles.

- Long-Run Average Cost (LRAC): In a perfectly competitive market with constant input costs, the LRAC curve for perfect complements exhibits a distinct "corner point" at the ideal input ratio. This point represents the most cost-effective way to achieve a specific output level. Any deviation from this ideal ratio results in an unknown average cost. Imagine a scenario where you have more welders than assemblers in a bicycle production line. This creates excess capacity for welding, while assembly becomes the bottleneck in production. The resulting average cost per bicycle becomes difficult to calculate, as you're essentially paying for unused capacity on the welding side.
- Analogy: Consider a peanut butter and jelly sandwich production line. One task requires workers to spread peanut butter, while another requires workers to spread jelly. To produce a sandwich, both tasks must be completed, and they likely require a fixed ratio of workers (e.g., 1 peanut butter spreader to 1 jelly spreader). Employing only peanut butter spreaders or only jelly spreaders would yield no sandwiches.

Organizations must comprehend the dynamics of perfect complementarity in order to optimize their manufacturing processes. It emphasizes the importance of meticulously planning and scheduling tasks, ensuring that complementary resources are available in the correct proportions. Organisations can arrange complimentary inputs into a production symphony where each component harmonizes to produce the best possible outputs by realising how interwoven they are.

Graph 2 – Isoquants when inputs are Perfect Complementary.



Source: Giulio Palomba

While perfect substitutability and complementarity provide a helpful framework, real-world production processes are more nuanced. Tasks are frequently interconnected, and worker performance is influenced by factors other than merely skill sets. This is where the concept of imperfect substitutability and complementarity comes in. This is an area where technological developments are crucial because they enable the decomposition of difficult jobs and the development of a workforce that is more flexible.

Imperfect Worker Substitutability and Technological Advancements: Real-world organizations function in a more nuanced environment characterized by **imperfect substitutability**. Tasks are often interrelated, and worker performance hinges on factors beyond individual skillsets (Emese Tokarčíková, 2015). However, technological advancements offer promising avenues for fostering greater worker substitutability, albeit with limitations.

One key strategy lies in automation and task standardization. Repetitive tasks that require minimal human intervention can be effectively delegated to robots, software, or

machinery (Michaels, 2018). This not only reduces reliance on human labour but also creates a more standardized task landscape. In such an environment, worker skills become more fungible, as the core requirements for task completion become more uniform. For instance, the automation of assembly line tasks in manufacturing reduces the need for specialized knowledge in operating specific equipment, making workers with similar skillsets in mechanical operations more interchangeable (Ronald MacDonald, 2007).

Technology platforms may also serve as enablers to boost teamwork and communication across teams engaged with various projects. Even in situations where employees are geographically dispersed, these platforms facilitate easy information sharing, knowledge exchange, and real-time issue resolution. This encourages a more cooperative workplace where information is not as compartmentalized and team members physical proximity to one another is not as crucial to job completion (David Spencer, 2021). Even if the manufacturing facility is situated in a different nation than the design team, cloud-based project management solutions may facilitate communication between the two groups, enabling quicker iteration cycles and better product quality.

Investing in cross-training programs also presents a viable approach to enhance worker substitutability. By equipping workers with skills relevant to multiple tasks within their domain, organizations can create a more adaptable workforce. This strategy mitigates the impact of worker absences or fluctuations in workload as personnel can be readily deployed to different tasks within their expanded skillset. For instance, cross-training customer service representatives in both product knowledge and technical support

allows them to handle a wider range of customer inquiries, reducing wait times and improving overall customer satisfaction (Akriti Chaubey, 2021).

However, technology-enabled performance analytics and monitoring provide an additional useful tool for promoting worker substitutability. Organizations can obtain data-driven insights on skill gaps and areas for progress by tracking individual and team performance across various jobs. This makes it possible to create more effective workflows and to implement targeted training interventions. Call centers data analysis, for instance, can highlight trends in consumer requests and pinpoint areas where specialized technical expertise is most important. The training programmers for customer care agents can then be customized using this information, guaranteeing that they have the abilities needed to handle a greater variety of consumer concerns more skilfully (David Spencer, 2021).

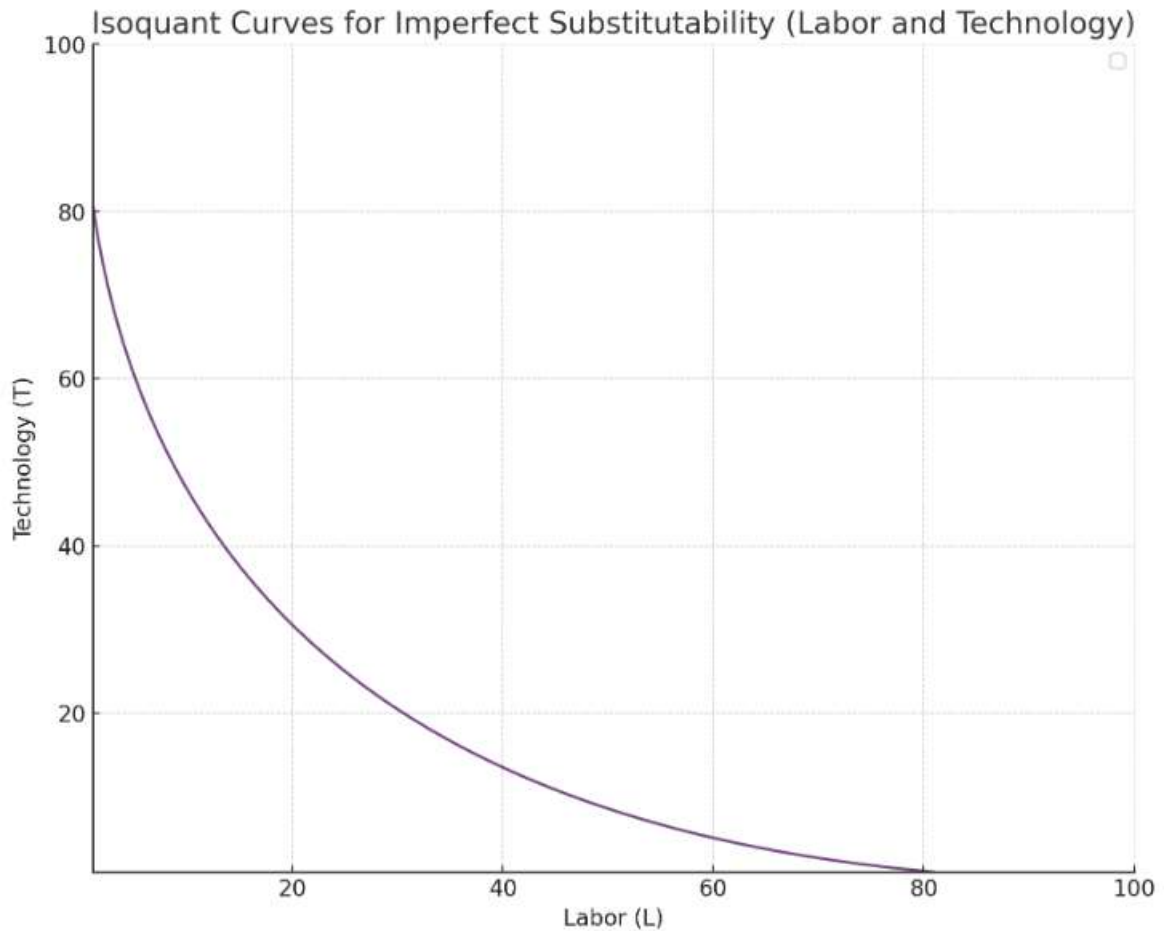
Nevertheless, it's crucial to acknowledge the inherent limitations of technology in achieving perfect worker substitutability. **Complex tasks** will likely continue to demand specialized skills and experience that are difficult to fully replicate through automation or training programs. For instance, the intricate decision-making and problem-solving required of surgeons cannot be easily replaced by surgical robots, even with advancements in artificial intelligence.

Interpersonal relationships and team dynamics are also significant variables in the role of overall productivity. While technology can help with collaboration and interaction, it cannot fully replicate the synergy created by effective teamwork, trust, and shared goals. Human interaction is essential because humans can anticipate issues, bounce ideas off one another, and adjust to unforeseen events. These are aspects of human interaction that technology is now unable to imitate. For example, the creative

cooperation of a copywriter, graphic designer, and social media professional is typically critical to the success of a marketing campaign. The team's ability to collaborate effectively and capitalize on each member's unique abilities is ultimately what will determine the campaign's success, even while technology can facilitate communication and task distribution (Oyefusi, 2022).

It's critical to recognize how these technologies are always evolving. The integration of new functions that were not present before characterizes this progression. For example, the use of AI algorithms allows for the description of objects and circumstances to be used to create new artistic expressions. Considering recent developments, the idea that artistic expression was once thought to be entirely human has undergone a substantial reevaluation.

Graph 3 – Isoquants Curves for imperfect Substitutability (Labor and Technology)



Sources: Ecograph

The illustration we're examining showcases a fascinating economic concept: isoquant curves. combinations of the two primary production inputs, labour (L) and technology (T), inside a production function with imperfect substitutability that can provide the same amount of output. Each distinct isoquant represents a specific output level, acting as a roadmap for producers seeking to navigate the landscape of resource allocation. Here's the key takeaway: unlike perfect substitutes, where one input can completely replace another without impacting output, labor and technology in this scenario demonstrate a more nuanced relationship. They cannot be swapped freely without consequences. It is possible that as we move along a certain isoquant, we will use less technology and more labour at the same time. This strategic adjustment maintains the

output level, but it's crucial to note that the rate of substitution between these factors isn't constant. This very characteristic – the variable substitution rate – underscores the imperfect nature of their relationship.

examining the other side of the coin, the idea of **Imperfect complementarity and Technological Advancements**, where specific tasks require specific combinations of workers and machines for optimal output, that has long fascinated economists. But as for Perfect substitutability achieving this ideal state directly might not be possible, technological advancements are undeniably influencing the degree of complementarity between tasks and workers. Let's delve into how technology is reshaping this intricate dance.

A critical strategy in contemporary production systems involves the decomposition of complex tasks into smaller, more manageable subtasks. By allowing employees to specialize, defined tasks, this method improves accuracy and efficiency and highlights the growing significance of automation in this process. For instance, industrial robots are skilled at performing physically taxing or repetitive subtasks in intricate assembly lines. This technological integration frees human workers to focus on tasks that capitalize on their unique cognitive and physical capabilities, such as critical thinking, creative problem-solving, and dexterous manipulation (Jay Dixon B. H., 2021). Tasks become more simplified, which makes the production system more adaptable. This flexibility potentially loosens the rigidities associated with the concept of "perfect complementarity" in production theory. In a system with highly modular tasks, however, the specific allocation of human and machine resources can potentially be adapted to meet changing production demands or address unforeseen challenges.

Technology has transcended its role as a mere tool instead, it can now work with humans to enhance their abilities. This synergy blurs the lines of perfect complementarity and ushers in an era of human-machine collaboration. This idea is explored in several study fields. Wearable robotic suits and exoskeletons, for example, have great potential to improve human strength and endurance. Imagine an exoskeleton-clad construction worker performing duties that formerly required two people to complete (Ashraf, 2018). This expansion of capabilities not only boosts productivity but also broadens the scope of work that one employee can handle. As a result, there may be less need for a particular skill sets for specific tasks, which could result in a workforce that is more adaptable.

The landscape of automation is undergoing a significant transformation with the emergence of intelligent automation systems. Unlike their robotic equivalents that are predetermined, these systems use artificial intelligence (AI) to reach a new degree of flexibility. Their capacity to move beyond pre-programmed tasks and negotiate changeable surroundings is a crucial distinction. According to different research, this developing field has the potential to upend conventional labour arrangements by reducing the need for highly specialized human skill sets in addition to strict automation. Advanced learning skills are the foundation of intelligent automation. These systems can process data continually, find trends, and improve over time by utilizing machine learning techniques (Zirar, 2023). They can manage a wider variety of subtasks inside a complex process and adjust to unforeseen events that may develop during operation thanks to this iterative learning process.

Imagine a production line staffed not by a collection of specialized robots, but by a single intelligent system. This flexible autonomous agent may switch between welding,

assembly, and even simple quality assurance jobs with ease. The increased flexibility and efficiency that such a system offers are just two examples of the revolutionary potential that intelligent automation holds for a variety of sectors.

2.3 The Modern Manufacturing Landscape: Efficiency and Adaptability

The modern manufacturing landscape demands a delicate balance between efficiency and adaptability. Standardised procedures provide efficient manufacturing, but flexibility is needed to respond to changes in the market and in the characteristics of the product.

According to the National Institute of Standards and Technology (2023), standardisation is the process of creating consistent specifications for goods, procedures, and services.

Within production systems, this translates to consistent data formats, communication protocols, and physical connections between machines and software in the work environment. This uniformity creates a foundation for interoperability – the ability of diverse technologies to seamlessly exchange information and function cooperatively (Wang, 2017).

The interplay between standardization and interoperability unlocks a myriad of benefits for task and production flexibility. First of all, it makes job and production line reconfiguration easier and eliminate the need for custom-built solutions, enabling a modular approach. Manufacturers are able to easily adjust to shifting market needs or product variants because to this "plug-and-play" flexibility. Consider a production line that produces various phone models. Robotic arms and sensors are examples of standardized parts that can easily change to construct different versions without requiring significant changes.

Secondly, interoperability empowers a more dynamic workforce. Traditional production systems often rely on rigidly defined task-worker combinations, limiting employee flexibility and adaptability. By enabling seamless communication between technologies, interoperable systems can distribute tasks across different machines or workstations.

This facilitates the deployment of skilled workers across a range of jobs, optimizing resource utilization and promoting a more collaborative work environment. Because of standardized user interfaces throughout the production line, picture a skilled worker who can manage various equipment (Tolksdorf, 2024).

Although technology unquestionably has a big impact on how tasks are designed and how capable workers are, it's important to understand that technology has limitations. Some activities may still require the harmonic integration of human and machine inputs, especially those that demand perfect synchronization or adherence to specific safety protocols. Some researchers, emphasized on how important it is to carefully consider if putting technological ideas into practice will be financially feasible. In this assessment, the long-term advantages—like increased flexibility and efficiency—are weighed against the costs of automation and the possible loss of jobs (MARK MURO, 2019).

In addition, industrial systems can move away from the rigidities of perfect complementarity, substitutability and towards more flexible and effective structures thanks to the tools that technology offers. However, it is crucial to acknowledge the limitations of these advancements and ensure that technological progress complements rather than replaces human skills and capabilities within the production process.” technology should be used to enhance human capabilities in order to create a setting where machine efficiency and human knowledge may coexist harmoniously” (AbeZeid, 2019).

2.4 Methods for measuring substitutability

Understanding worker substitutability in the face of automation is a multifaceted challenge. While technology marches forward, the human element of work - skills, experiences, and adaptability - remains crucial. This complexity necessitates a research approach that goes beyond the limitations of traditional quantitative or qualitative methods alone. Enter the realm of mixed methods research, a strategic integration of both **quantitative** and **qualitative** techniques (Johnson, 2007).

Quantitative research shines in its ability to handle vast datasets, identifying trends and relationships across large populations. Consider assessing automation risk scores for entire industries or analysing salary data for millions of workers. This quantitative approach excels at uncovering broad patterns, allowing researchers to make generalizations and even predictions based on statistical evidence. However quantitative approaches often fail to provide an explanation for the "why" behind the observed facts. They offer an overview, illuminating "what" is going on without necessarily addressing the underlying causes or surrounding circumstances. This limitation can lead to a superficial understanding of complex phenomena, missing the nuances of how workers experience automation or the specific skills required to adapt alongside technology.

On the other hand, the complexity and breadth of the human experience are best explored using **Qualitative** research methodologies. In-depth interviews with workers, focus groups with industry experts, or ethnographic studies observing workplace interactions - these qualitative approaches provide rich, detailed insights that quantitative methods cannot capture. Consider exploring the particular duties that an employee carries out, the difficulties that automation presents, or the knowledge and abilities that they must acquire to function efficiently with technology. Through a

qualitative investigation, researchers are able to get to the "why" behind the facts and reveal the complex human component of worker substitutability. Qualitative research does, however, have limitations. It may be challenging to generalise the results of qualitative research to a larger population due to the frequently used smaller sample sizes. Additionally, the subjective nature of data interpretation in interviews or focus groups can introduce researcher bias. Instead, qualitative research can be more time-consuming and resource-intensive compared to quantitative methods.

This is where mixed methods research emerges. By strategically combining quantitative and qualitative techniques, researchers can address the limitations of each and gain a more comprehensive understanding of worker substitutability. The quantitative data provides a broad foundation, allowing researchers to identify areas for further exploration. Qualitative methods can then be employed to delve deeper into specific jobs, tasks, or skills identified through the quantitative analysis (Catalyst, 2021).

For example, in order to identify industries or occupations with high risk of human substitutability, an investigator would begin by analysing salary data and automation risk ratings (quantitative). Subsequently, they might carry out in-depth interviews with employees in those industries to gain insight into the particular tasks that are being automated, the effects on their jobs, and the skills they anticipate being essential in the future (qualitative). The utilisation of mixed methods approach provides a more comprehensive depiction of worker substitutability, elucidating the level of automation as well as the particular competencies and education required for workers to prosper in the dynamic labour market.

In rapidly evolving labor markets, accurate measurement of worker substitutability is essential for strategic workforce planning, assessing the effects of technological

advancements, and developing educational and training program. While mixed methods provide a thorough approach, other methodologies also offer valuable insights:

Elasticity of Substitution (EoS), a quantitative technique that examines how simple it is to replace labour with alternative inputs throughout production process. Like that, the concept of **cross-price elasticity of demand** studies the impact of a shift in the pay of one labour type on the demand for another. These methods offer detailed quantitative insights but require robust data and expertise in economic modelling.

For qualitative insights, proponents of competency-based learning recommend methods like skill **overlap analysis** and **task-based analysis**. Skill overlap analysis compares the skill sets required for two jobs, while task-based analysis examines the similarity of the actual tasks performed. These approaches provide valuable insights into substitutability but rely on subjective evaluations and may not be easily scalable for large datasets.

For scenarios when a rapid initial analysis is needed, less complicated techniques such as **wage correlation analysis** might be utilised. This technique examines the correlation between the wages of two occupations. A high correlation suggests some degree of substitutability. However, it's crucial to acknowledge that wage correlation doesn't account for other factors affecting wages and may provide misleading results. For a more comprehensive understanding of labor market dynamics, researchers utilize job transition analysis (Xu Liu, 2024). This technique keeps track of employees employment changes throughout time. Analyzing job transition patterns reveals how readily workers with certain skillsets shift to other occupations. Although longitudinal workforce data is necessary for this strategy to yield useful insights, it may not always be easily accessible.

The choice of a methodology is based on an accurate evaluation of available data sources, and the objectives of the analysis. However, for a detailed understanding of the substitutability landscape and its implications for workforce planning, job transition analysis or a combination of methods might be more appropriate. In order to measure worker substitutability successfully, it is vital to understand the strengths and limits of each method and choose the appropriate tool. This makes it easier to analyse labour market trends and prepare for the always changing labour market, which eventually leads to more strategic decision-making and resilient workers.

The elaborateness of worker substitutability necessitate an approach to research that transcends the confines of conventional techniques. With its thoughtful blending of quantitative and qualitative methodologies, mixed methods research provides an effective means for scholars to obtain a deep and thorough comprehension of this important problem. Through the integration of the advantages of both methodologies, scholars may shed light on the future direction of workforce development and guarantee a future in which technology and people can collaborate effectively.

In light of the comprehensive examination and findings collected, I propose a methodology that integrates the quantitative approach of Elasticity of Substitution (EoS) with the qualitative approach of Task-Based Analysis (TBA) to thoroughly assess worker substitutability. This combined framework provides businesses with a robust and practical tool to effectively evaluate the extent to which one worker can replace another. The following chapters delve into the specifics of these methodologies.

Elasticity of Substitution (EoS) as a quantitative measure for analyzing Worker Substitutability

Elasticity of substitution (EoS) is a crucial economic concept that helps quantify worker substitutability. It measures the degree to which one input (like labor) can be replaced by another (like different types of workers or even technology) within the production process.

Its analytical definition is:

$$\sigma = \frac{\frac{\partial K/L}{K/L}}{\frac{\partial |\text{SMST}(L, K)|}{|\text{SMST}(L, K)|}} = \frac{\frac{\partial K/L}{K/L}}{\frac{\partial |\text{SMST}(L, K)|}{|\text{SMST}(L, K)|} \cdot \frac{K/L}{K/L}} = \frac{\partial \ln K/L}{\partial \ln |\text{SMST}(L, K)|}$$

Source: Giulio Palomba Programma 2020/2021

Where the ratio K/L is called capital intensity. In the latest version, the SMST is in absolute value because it is the argument of the logarithm function (existence condition).

The elasticity of substitution takes on positive values, i.e. greater than zero. This means that, moving along a given isoquant, it happens that (Giulio, 2021):

- If K (therefore L ↓) increases, SMST(L,K) ↓ (the isoquant shifts towards the origin). This is because the marginal product of capital decreases.
- If L (therefore K ↓) increases, SMST(L,K) ↑ (the isoquant shifts away from the origin). This is because the marginal product of capital increases.

The greater the elasticity of substitution, the greater the possibility of substituting one input for another. In detail:

- If $\sigma = 0$ in perfectly complementary (right-angle isoquant),
- If $0 < \sigma < 1$ complementary input (isoquant with high curvature),
- If $\sigma \geq 1$ input substitute (isoquant with little curvature),
- If $\sigma = 1$ input perfect substitutes (linear isoquant, hence constant SMST),

Elasticity of Substitution (EoS) is a concept that goes much beyond worker substitutability as a simple metric. EoS provides a potent strategic lens for companies negotiating the constantly changing environment of work that is being transformed by technology advancements (Dachner, 2021). Now let's explore how EoS translates into information that organisations may use to improve the way they operate:

1. Automating tasks and proactively organizing the workforce: Businesses can obtain a full understanding of the elements of their operations that are most vulnerable to technological replacement by examining EoS through the lens of automation of tasks possibilities. Tasks with high EoS - those readily replicated by technology - become prime candidates for automation. This foresight empowers firms to make informed decisions regarding investments in automation technologies. This kind of foresight enables businesses to invest in automation technology with knowledge and confidence. Moreover, EoS is essential for proactive workforce planning in the event that jobs are lost due to automation. Recognizing which tasks are likely to be automated allows businesses to proactively develop reskilling or upskilling programs to support affected employees in transitioning to new roles within the organization (Dupuy Arnaud, 2006).

The concept of Elasticity of Substitution (EoS) offers businesses a powerful tool that goes beyond simply measuring worker replaceability, by identifying low-EoS talents, allows for a more comprehensive knowledge of a company's personnel. These are the critical skillsets that are difficult to replicate with technology and are in high demand within the labor market (Farrow, 2022). Prioritizing these fundamental abilities enables businesses to strategically fund employee training initiatives that prepare them for the future, securing both a competitive advantage and a future-proof workforce.

This approach to skill development yields significant benefits for both employers and employees. Let's explore how (Stern, 2009):

- **Future-Proofing the Workforce:** Low-EoS skills are becoming essential for long-term success in the face of rapid technological improvements. Equipping employees with these crucial skillsets enhances their adaptability and ensures the workforce remains relevant in the evolving work landscape.

- **Keeping a Competitive Edge:** A staff with low-EoS capabilities puts a business in a strategic position within the industry. Their capacity to handle difficult jobs that are difficult to automate gives them a substantial competitive edge. Businesses that place a high priority on these competencies will be able to draw in and keep top personnel, which will ensure their success in an ever-evolving technology landscape.

- **Investing in Employee Value:** Employee empowerment and professional development are two outcomes of training programs that foster low-EoS talents. This investment not only fosters a sense of loyalty and strengthens the employer-employee relationship but also increases the value proposition for employees seeking career advancement opportunities.

Some Examples:

- **A Bank in Transformation:** Analyzing EoS might reveal that many tasks performed by tellers have a high EoS, indicating these can be automated through ATMs or online banking with virtual assistant (IA) (Brynjolfsson, Rock, & Syverson, 2016). Armed with this knowledge, the bank can invest in retraining tellers for customer service roles, which typically have a higher EoS due to the human touch and complex problem-solving required.

- **Manufacturing in the Age of Automation:** Identifying tasks within the assembly line with high EoS paves the way for automation. By understanding which tasks are easily replaceable, the manufacturing company can focus its resources on developing the skills of workers who will maintain and operate the new technology (tasks with lower EoS). This ensures a smooth transition towards automation and minimizes job losses by focusing on upskilling workers for the new technological environment.

Although Elasticity of Substitution (EoS) provides an excellent framework for workforce capacity analysis, it must be remembered to recognise its limitations and take into account several considerations beyond the strictly technical features it covers. A closer look at some key limitations and restrictions, is provided below:

- **EoS as a Theoretical Framework:** This framework mainly concentrates on whether or not it is technically possible to substitute employees with technology, taking into account the type of jobs that need to be completed. Beyond the technological framework of EoS, real-world issues can have a substantial impact on worker substitutability. demonstrates how important it is for elements like morale among workers, team dynamics, and even rules to be considered when determining how well a team performs (David H. Autor, 2023). For instance, even if individual team tasks have a high EoS, a group of highly driven individuals with great communication skills may still be capable to complete tasks effectively. This emphasizes the importance of considering the human element and its potential to compensate for technical substitutability.
- **Data Availability Challenges:** Utilizing EoS effectively requires accurate data on the nature of tasks and the skills required to perform them within an organization. On

the other hand, companies might not have easy access to data regarding the EoS of various tasks performed by employees. This can be a significant obstacle in implementing an EoS-based workforce strategy. Companies may need to carry out internal research to examine worker skills and task characteristics in order to overcome this difficulty. As an alternative, industry benchmarks can offer points of comparison for estimating the efficiency of certain tasks (JR, 1987). However, it's crucial to recognize that industry benchmarks may not perfectly reflect the specific context of a particular organization.

Businesses can use EoS as a workforce planning tool more successfully if they are aware of these drawbacks and consider the human factor. Utilizing it alongside other tools like human resource expertise allows for a more comprehensive approach to talent management in the face of evolving technological landscapes.

Task-Based Analysis as a Qualitative Measure for Analyzing Worker Substitutability

The dynamic nature of technology demands a sophisticated comprehension of worker substitutability, or the degree to which an employee's position can be readily filled by automation. While quantitative methods offer a broad picture of trends and risks (as discussed previously), a deeper dive into the specific tasks involved is crucial. This is where task-based analysis emerges as a powerful tool in the research arsenal.

Task-based analysis is used to break down and comprehend the particular task and responsibilities associated with various job roles. This method explores the type, complexity, and demands of the jobs that employees execute, providing a comprehensive understanding of worker substitutability that goes beyond simple statistics (Lambert, 2001). By examining these aspects, task-based analysis provides

rich insights into which tasks are susceptible to automation and which ones rely on unique human capabilities, making them harder to replicate with technology. Lets delve into the methodologies for Task-Based Analysis:

- Firstly, task-based analysis involves breaking down each job role into its component tasks. Each task's required knowledge, abilities, and experience are listed in depth, along with how frequently and how important they are to the job its proper position. By cataloging these elements, organizations can gain a clear picture of the intricacies involved in each position.

- Subsequently, each task's level of complexity and skill needs are evaluated. Factors such as problem-solving needs, decision-making processes, and the level of manual dexterity required are evaluated his stage is essential for figuring out how complex the activities are overall and what specific skills or expertise are required to complete them successfully (Buyukkarci, 2009).

- Another critical step is analyzing task overlaps across different job roles Organisations can find areas of skill overlap and distinguish between tasks that are exclusive to a function and those that are common across roles by comparing tasks. Understanding the adaptability and transferability of abilities within the workforce is made easier by this comparison.

- A significant part of task-based analysis is evaluating the potential for automation. The list of tasks that can be performed by both existing and future technologies highlights those that need for human intuition, creativity, or emotional intelligence—qualities that are hard to automate. In a time where technology is developing at a rapid pace, this assessment is essential for strategic planning.

- The final step involves synthesizing these findings. By combining data from task analysis with qualitative insights, organizations can form a comprehensive understanding of worker substitutability. This integrated approach reveals patterns and trends that inform strategic decision-making, helping organizations adapt to technological changes and workforce dynamics (Seyyedi, 2012).

Task-based analysis has limitations despite its detailed approach. The primary limitation is subjectivity. The analysis relies heavily on subjective evaluations of tasks, which can introduce bias. Results consistency may be impacted by how many analysts rate a task's complexity and skill requirements. This process is time-consuming and resource-intensive. Conducting detailed task-based analysis requires significant time and effort, particularly when gathering qualitative data through interviews and observations. This can be a substantial undertaking for organizations, especially those with limited resources. Another drawback is scalability. It can be difficult to apply task-based analysis to big datasets or to different work responsibilities. Due to its precise nature, the method is not easily scaled, which may limit its usefulness in large organisations with a wide range of job roles (Lai, 2023). Furthermore, because work is dynamic, employment responsibilities and duties are always changing, especially in light of technology improvements. The requirement for frequent revisions to the analysis to maintain its applicability raises the resource requirements.

Example:

Within the healthcare sector, task-based analysis can differentiate between jobs that require human skill, such as patient diagnosis and treatment, and tasks that are administrative and can be automated, including scheduling and billing. This analysis

can guide training programs for administrative staff, helping them transition into roles that support clinical functions and enhancing overall operational efficiency.

Enhancing Organisational Functions: It provides a number of useful advantages for businesses looking to improve their operations. Several useful advantages of this analytical method include strategic personnel planning, increased productivity, staff development, and well-informed technology investment.

One of task-based analysis's greatest advantages is its capacity to assist strategic workforce planning. Organizations can anticipate labour shifts by determining which tasks are most susceptible to automation. Understanding these distinctions allows companies to develop reskilling and upskilling programs that ensure employees are ready for new roles that utilize their unique human capabilities. This proactive strategy fosters a culture of continuous learning and growth by empowering individuals to grow and adapt while also reducing the risks associated with automation (Jack, 2023).

Another ability of this analysis is in identifying inefficiencies in task allocation and workflow. By closely examining how employees divide up their work, businesses can pinpoint areas where resources are either inadequate or wasted. This reallocation improves overall productivity while streamlining operations. Workers can concentrate on assignments that call for creativity, critical thinking, and decision-making—domains where human judgement is most valuable. As a result, the organization operates more efficiently, leveraging both human and technological capabilities to their fullest potential.

Also, it helps to focus on skills required for non-automatable jobs. Organisations can customize their employee development programs to improve these abilities by identifying tasks that are human intervention-intensive by nature. This focus on personal

and professional growth not only improves employee satisfaction but also contributes to career advancement. Employees who feel valued and see opportunities for growth are more likely to be engaged and motivated. This methodology cultivates a workforce that is more resilient and adaptive, able to flourish in a technologically advanced setting (Celik, 2017). Ultimately, investing in employee development ensures that the organization remains competitive and agile in the face of ongoing technological changes.

When purchasing automation technologies, organisations can make well-informed decisions if they fully comprehend the responsibilities involved in the various job categories. By prioritizing technologies that address the most repetitive and labor-intensive tasks, companies can maximize their return on investment. This strategic approach to technology investment allocates resources where they will have the greatest impact. Robotic process automation, on the other hand, may be the best option for businesses with a large volume of repetitive manual procedures, whilst investing in sophisticated data analysis tools may be more advantageous for those with data-intensive activities. By aligning technology investments with task-based insights, organizations can achieve greater efficiency, cost savings, and operational effectiveness. Is a helpful strategy for companies trying to improve their operations (Feng, Qi, Liu, Dong, & Liu, 2023). Businesses may proactively organise their workforce, increase productivity, support employee growth, and make well-informed technology expenditures by utilising this strategy.

CHAPTER 3. The Rise of New Technologies and Worker Replacement

The rapid growth of technologies like automation, robots, and artificial intelligence (AI) is changing the nature of employment in a way that is beneficial as well as negative to society. While these technologies offer unprecedented opportunities for efficiency and economic growth, they also pose significant challenges, particularly in terms of job displacement and the socio-economic impacts that follow (Frank, 2022). The primary considerations of worker replacement in the era of automation will be addressed throughout this chapter, along with technological, social, and economic factors to take into account and suggestions for navigating this complex environment.

The potential economic benefits of automation are undeniable. Businesses can improve product quality, cut expenses, and expedite operations by automating monotonous and repetitive jobs. This increased efficiency can lead to substantial economic growth and the creation of new industries and job roles. This optimistic view is, however, overshadowed by the threat of job displacement. As automation encroaches on various sectors, particularly those reliant on manual labor, workers may find themselves facing unemployment (Wu, 2024). This could set off a chain reaction that results in decreased consumer spending, wage stagnation, and economic instability. The rise of technology had an impact also on the **Social impact**: The social implications of automation-induced job displacement are equally profound. Rising unemployment rates and widening income inequality are potential outcomes as lower-skilled jobs become increasingly automated. These economic disparities can exacerbate social tensions and contribute to the erosion of social cohesion. Furthermore, it is impossible to overlook the psychological effects on displaced workers. Anxiety, despair, and a loss of purpose can arise from losing a source of income. Sociologists and policymakers are grappling

with these challenges. Some work highlights the need for societies to adapt and develop strategies to mitigate the negative consequences of automation. In the next chapter we are going to understand these new technologies that are replacing workers. To fully comprehend the intricacies of this technological revolution and its potential impact on the workforce, we must delve deeper into the specific nature of these emerging technologies. In the following chapters, we will explore the capabilities and limitations of automation, robotics, and AI, examining how these technologies are being deployed across various industries and the implications for employment. By understanding the technological landscape, we can better assess the challenges and opportunities that lie ahead and develop strategies to mitigate the negative consequences while maximizing the benefits for society.

The conversation around artificial intelligence (AI) and robots often overlaps, yet it's essential to distinguish between the two when discussing their substitutability for human labor. While both technologies have made significant strides, their implications for the workforce and their capabilities in replacing human tasks differ in nuanced ways.

The rapid growth of technologies like automation, robots, and artificial intelligence (AI) is changing employment in both positive and negative ways. While automation offers efficiency and economic growth, it also poses significant challenges, such as job displacement and socio-economic impacts. As automation encroaches on sectors reliant on manual labor, workers may face unemployment, decreased consumer spending, wage stagnation, and economic instability. The social implications of automation-induced job displacement include rising unemployment rates, widening income inequality, and

psychological effects on displaced workers. Sociologists and policymakers are grappling with these challenges, and societies need to adapt and develop strategies to mitigate the negative consequences of automation. Understanding the capabilities and limitations of automation, robotics, and AI is crucial for assessing the challenges and opportunities and developing strategies to maximize benefits for society.

3.1 Artificial Intelligence: the rise of AI and its potential to automate tasks.

The term "artificial intelligence" (AI) has been the subject of extensive debate and exploration among researchers and scholars across diverse scientific disciplines. As AI technology continues to evolve at an unprecedented pace, its definition has undergone significant refinement and expansion. In 1955, John McCarthy, who is widely recognized as the originator of the term "artificial intelligence," provided a foundational definition: "AI is the science and engineering of making intelligent machines, especially intelligent computer programs" (McCarthy John, 1995). This early conception of AI focused on the creation of machines capable of emulating human cognitive functions, such as perception, learning, reasoning, and problem-solving. Subsequently, Kaplan and Haenlein (2019) offered a more nuanced perspective, emphasising AI's ability to adapt and learn from data. They defined AI as "the ability of a system to accurately interpret external data, acquire knowledge from such data, and apply those acquired insights to accomplish specific goals and tasks through flexible adaptation" (Andreas Kaplan, 2019).

This definition underscores AI's capacity to learn and evolve over time, enabling it to perform tasks in a more dynamic and adaptable manner. Other scholars have emphasised AI's ability to replicate specific human functions. (Jabbour Ana, 2018) highlighted AI's capability to "mimic human cognitive processes, encompassing functions such as perception, learning, reasoning, and decision-making" (Savva Manolis, 2018). This perspective underscores AI's potential to bridge the gap between human and machine intelligence. A critical distinction that often goes overlooked is the differentiation between strong and weak AI. Strong AI, also known as artificial general intelligence (AGI), represents the hypothetical ability of a machine to achieve human-

level or even surpass human intelligence in all domains. Current AI technologies, which are largely based on weak AI principles, operate within predefined rules and parameters, lacking the ability for independent thought or self-direction. Strong AI, on the other hand, would possess the capacity to autonomously establish its own rules and goals (Wolfe, 1991). This level of autonomy would allow strong AI to operate with a degree of self-awareness and free will, akin to human intelligence. However, it is important to note that strong AI remains a theoretical construct and has not yet been realised in practice. In the context of workforce concerns regarding AI, it is crucial to have a clear understanding of the various AI capabilities and their implications. Understanding the distinction between strong and weak AI can help workers navigate the potential impacts of AI on their jobs and the broader workforce. Additionally, comprehending the evolving nature of AI and its potential trajectory can inform informed decision-making and proactive strategies to address the challenges and opportunities presented by this technology. As AI continues to evolve and permeate various aspects of society, it is essential to maintain a dialogue among

researchers, policymakers, and the public to ensure that AI development is guided by ethical principles and societal well-being. By fostering open discourse and understanding, we can harness the potential of AI while mitigating potential risks and ensuring that this transformative technology serves the betterment of humanity. The field of AI is witnessing a surge of innovations, driven by advances in computing power, data availability, and machine learning techniques. These advancements are opening up new possibilities for AI applications across various domains. Generative AI models have emerged as a transformative force in the realm of artificial intelligence, offering the remarkable ability to produce new creative content that rivals human-

generated works, encompassing images, text, and music (Goodfellow, 2014). These sophisticated models are trained on vast datasets, enabling them to extract underlying patterns and relationships, which they then utilise to generate entirely original creations that align with these patterns and relationships. The potential impact of generative AI models extends across diverse industries, poised to revolutionise artistic expression, entertainment, and education. In the realm of art, these models can produce captivating images, sculptures, and musical compositions that blur the boundaries between human and machine creativity (Alamir, 2021). In the realm of entertainment, generative AI models can personalise user experiences by generating tailored content, such as personalised movie recommendations or customised music playlists. In the realm of education, generative AI models can create personalised learning materials, adapting to individual student needs and preferences (Bhutoria, 2022). By doing so it substitute workers in their activities creating a disruptive work environment if not applied in the correct way.

The field of Explainable AI (XAI) has gained significant traction, aiming to enhance the transparency and interpretability of AI models (Shams Amiri Shideh, 2021). XAI techniques empower humans to comprehend the reasoning behind AI decisions, fostering trust in AI systems and enabling informed decision-making. This is crucial for ensuring that AI is employed in a fair and unbiased manner, mitigating the risk of discrimination and promoting ethical AI practices. XAI encompasses a range of techniques, each addressing specific aspects of AI explanation ability. Techniques focus on explaining a particular decision made by an AI model, while global explainability techniques provide a broader understanding of how an AI model operates. Counterfactual explainability techniques shed light on the factors that influenced a

particular decision, illustrating how a small change in input data could have led to a different outcome (Kusner Matt J, 2017). As AI continues to evolve, it is essential to acknowledge the potential concerns and challenges it may pose. Job displacement is a major concern, as AI systems become increasingly sophisticated, potentially automating tasks currently performed by humans. This could lead to job losses in certain industries, particularly those heavily reliant on routine tasks. Bias and discrimination are further concerns, as AI systems are trained on data that may contain inherent biases (Selenko, Artificial Intelligence and the Future of Work: A Functional-Identity Perspective taking, 2022). These biases can inadvertently perpetuate societal inequalities, leading to discriminatory outcomes. For instance, an AI system trained on a biased dataset of resumes might be more likely to favour male applicants over female applicants. Ethical implications also demand attention, as AI systems could be misused for malicious purposes, such as surveillance, manipulation, and warfare. It is imperative to establish robust ethical guidelines and regulations to ensure that AI is developed and utilised responsibly and ethically. To mitigate the potential risks and fully embrace the opportunities of AI, a proactive approach is essential. Investing in AI education and training will equip workers with the skills to adapt to the changing workforce. Developing AI safety measures will help minimise bias and discrimination, ensuring that AI systems operate in a safe and secure manner. Establishing ethical guidelines will guide the development and utilisation of AI in a responsible and ethical manner.

The rapid advancement of artificial intelligence (AI) has ushered in an era of transformative possibilities, with the potential to address complex societal challenges and enhance business efficiency. However, alongside these advancements, several ethical concerns have emerged, particularly in the context of data handling and

decision-making processes. The increasing availability of extensive human behavioural data and the development of sophisticated machine learning algorithms have facilitated a growing reliance on algorithms for decision-making. While this reliance holds promise for improved efficiency and accuracy, it also raises concerns about the potential for misuse of sensitive data. A significant ethical concern stems from the potential for algorithms to embed and perpetuate biases that may exist in the data they are trained on (Lepri Bruno, 2017). This can lead to unfair treatment of certain groups of individuals, particularly in sensitive domains such as hiring, loan applications, and criminal justice systems. For instance, an algorithm used to assess loan applications may discriminate against individuals from minority groups based on historical data that reflects systemic biases. Despite these concerns, algorithmic decision-making processes have the potential to produce more objective and equitable results compared to human decisions (Floridi Luciano, 2018). To harness this potential, it is crucial to ensure that algorithms are transparent and accountable, and that individuals have the right to understand the basis of decisions made about them. This transparency and accountability can be achieved through techniques such as explainability AI (XAI), which aims to make AI models more understandable and interpretable. Another ethical concern arises from the increasing use of AI in marketing, where the potential for manipulation and the erosion of consumer autonomy is a pressing issue (Alexander, 2019). The utilisation of historical data to calculate individual-level willingness-to-pay estimates could lead to extreme levels of dynamic pricing, potentially disadvantaging certain consumer groups. Additionally, the showcasing of items that customers had previously interacted with or extensively examined could induce impulse buying, potentially undermining their ability to make informed and deliberate purchasing decisions. To address these ethical

concerns and ensure responsible AI development and deployment, it is essential to establish robust ethical guidelines and regulations. These guidelines should emphasise the importance of human oversight and control over AI systems, as improper reliance on these systems may lead to the delegation of critical tasks and decision-making to autonomous systems. Additionally, mechanisms for data governance and transparency should be implemented to safeguard against misuse of sensitive data and ensure that individuals have the right to understand and control how their data is used. Another area where AI can play a critical role is in employee retention. Factors like lack of skilled workforce, economic growth and employee turnover demand to devise policies to increase employee retention. There are different human resource (HR) practices employed by the organisation to increase the retention level. Employee retention consists of procedures through which employees are boosted to become part of the organisation for a longer period of time until he/she gets retired or until the project gets completed. For achieving individual as well as organisational goals, it is very much essential to retain talented employees. The HR manager must know how to attract and keep good employees because these are the employees who can make or break the organisation's goodwill (Reza Lidia Sari, 2022). Successful employee retention does not rely on a single strategy. The decision of an employee to stay in the organisation is effected by a number of factors depending on a variety of elements like the individual's age, the family situation, mentoring, career and learning opportunities, good benefits, networking and the external job market or job title the retention of employees has become the major problem facing today's organisation, this one should opt for the retention approach that amalgamates a distinct culture, pay, total rewards, and value key talent by making them feel important (Zingheim, 2009). A number of organisations are

conducting research to find out the effect of different HR practices on employee retention. Training and development programs can increase retention when they meet the needs of the employees. Artificial intelligence (AI) can significantly influence employee retention by contributing to various aspects of HR practices and organisational strategies. Employee retention is a critical aspect of organisational success, and the integration of artificial intelligence (AI) can play a pivotal role in enhancing these efforts. AI technologies offer innovative solutions that align with contemporary HR practices, contributing to the creation of a work environment that attracts and retains talented individuals. AI influences retention through personalised employee experiences. By leveraging AI driven algorithms, organisations can analyse individual preferences, career aspirations, and learning styles. This enables HR managers to tailor development programs that resonate with the specific needs and goals of each employee, ultimately fostering a sense of engagement and loyalty (Selenko, 2022). Training and development programs, vital components of employee retention, can also benefit from AI. This technology can analyse skill gaps, recommend personalised training modules, and predict future skill requirements based on industry trends. By doing so ensures that training initiatives are not only relevant but also contribute directly to the professional growth of employees, making them more likely to stay within the organisation. Additionally, AI can play a crucial role in creating a positive work culture. By analysing employee sentiments through sentiment analysis tools, organisations can gain insights into the factors contributing to job satisfaction and identify potential areas of improvement. This information allows HR managers to implement targeted initiatives that enhance employee well-being and contribute to a positive workplace atmosphere (Selenko, 2022).

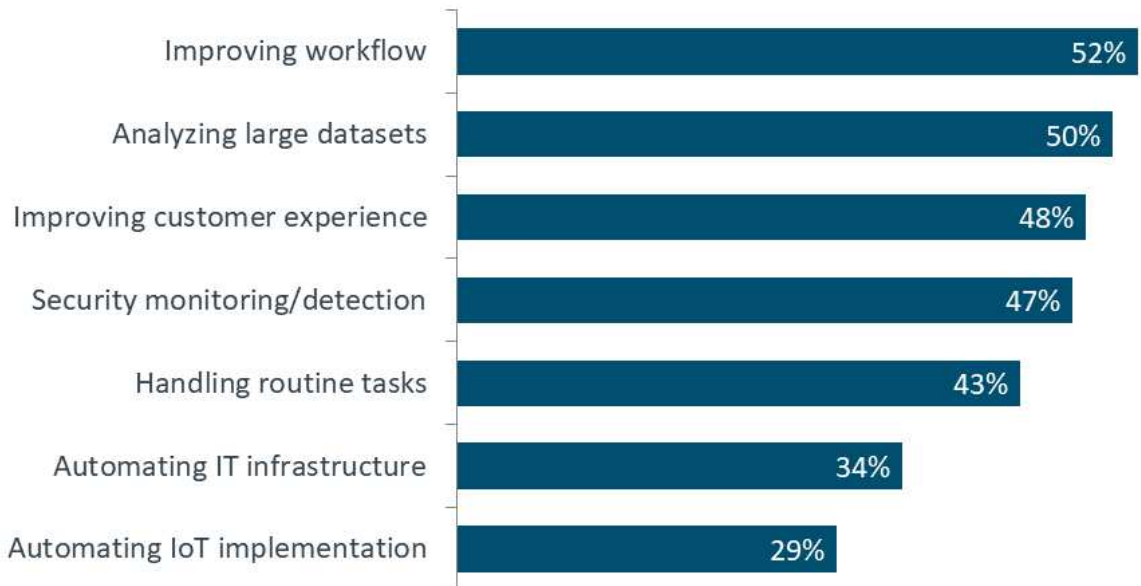
The advent of Industry 4.0 has led to an increased demand for automation, digitization, and agility in HR practices. AI has the potential to revolutionise HR practices, as it can enhance efficiency, accuracy, and decision-making in HR functions. One of the key areas where AI can make a significant impact in HR is recruitment and talent acquisition. I-powered algorithms can scan resumes and job applications to identify suitable candidates based on predefined criteria, reducing the time and effort required for manual screening (Umasankar Murugesan, 2023). In fact, the integration of artificial intelligence (AI) into human resource (HR) practices has raised a range of concerns about its impact on employee well-being, privacy, and fairness. While AI holds immense potential to enhance efficiency, streamline processes, and improve decision-making within HR, its implementation must be guided by ethical considerations and robust safeguards to mitigate potential risks. The use of AI-powered surveillance tools, such as Status Today, to track employee productivity and activities has sparked ethical debates regarding employee privacy and autonomy. These tools enable employers to monitor minute-to-minute activities, potentially leading to micromanagement and diminishing employee trust (Haenlein Michael, 2022). Autor Michael argue that AI surveillance raises concerns about the erosion of workers' privacy and the potential for employers to exert undue control over their employees' behaviours. Revealed by (Chen, 2023), asserts that algorithms, while not inherently discriminatory, can perpetuate biases embedded in the data they are trained on. This can lead to unfair treatment of certain groups of applicants or employees in hiring, performance evaluations, and promotions. For instance, algorithms trained on datasets that reflect historical hiring disparities may perpetuate these biases, inadvertently excluding qualified candidates from underrepresented groups. Despite these challenges, AI can also be harnessed to enhance

HR practices and improve employee well-being (Johnson Richard D, 2020). Highlight the potential of AI to streamline recruitment processes by matching candidate skills and abilities with specific job requirements, creating individualised profiles to identify the most suitable candidates. Further, AI can be used to personalise training and development programs, tailoring them to the needs and preferences of individual employees, leading to enhanced engagement and skill development. To mitigate the potential risks associated with AI in HR, organisations must adopt clear ethical guidelines and implement robust safeguards. Transparency and accountability are crucial, as employees should be informed about the use of AI in HR processes and have access to explanations for AI-driven decisions. Additionally, data governance practices should ensure that data used to train AI models is representative and unbiased, mitigating the risk of algorithmic discrimination. In today's rapidly evolving business environment, organisations are constantly seeking innovative approaches to enhance their human resource management (HRM) practices and achieve their strategic goals. This pursuit of excellence has led to the convergence of SHRM and AI, a synergistic partnership that holds immense potential to transform HR and drive organisational success. SHRM, defined as "the pattern of planned human resource deployments and activities intended to enable an organisation to achieve its goals" (Wright, 1992), encompasses a broad spectrum of strategic initiatives aimed at aligning HR practices with organisational objectives. These practices cover a wide range of functions, including talent acquisition, performance management, training and development, compensation and benefits, employee relations, and employee engagement. A branch of computer science that deals with the creation of intelligent agents, has emerged as a transformative force in the HR domain. AI's ability to analyse vast amounts of data,

provide predictive insights, and automate tasks offers organisations unprecedented opportunities to enhance their HR practices and achieve their strategic goals. The integration of AI into talent acquisition processes has revolutionised the way organisations recruit and hire top talent. AI-powered applicant tracking systems (ATSs) have streamlined the recruitment process by automating many of the tasks involved, such as screening resumes, identifying qualified candidates, and scheduling interviews. This automation has freed up HR professionals to focus on more strategic activities, such as developing talent acquisition strategies and building relationships with potential candidates (Shen, 2022). AI has also enabled organisations to go beyond traditional metrics of education and experience to identify and assess candidates based on their skills, personality traits, and cultural fit. AI-based tools can analyse social media profiles, online portfolios, and other digital footprints to gain a deeper understanding of each candidate's potential and suitability for the organisation. This personalised approach to candidate assessment ensures that organisations are making informed hiring decisions that align with their strategic goals. Traditionally, these tasks were the domain of human workers, forming the backbone of countless industries. However, the relentless march of technological progress has initiated a profound shift, where machines are increasingly assuming roles once exclusively occupied by people.

Graph 4 – Potential uses for AI

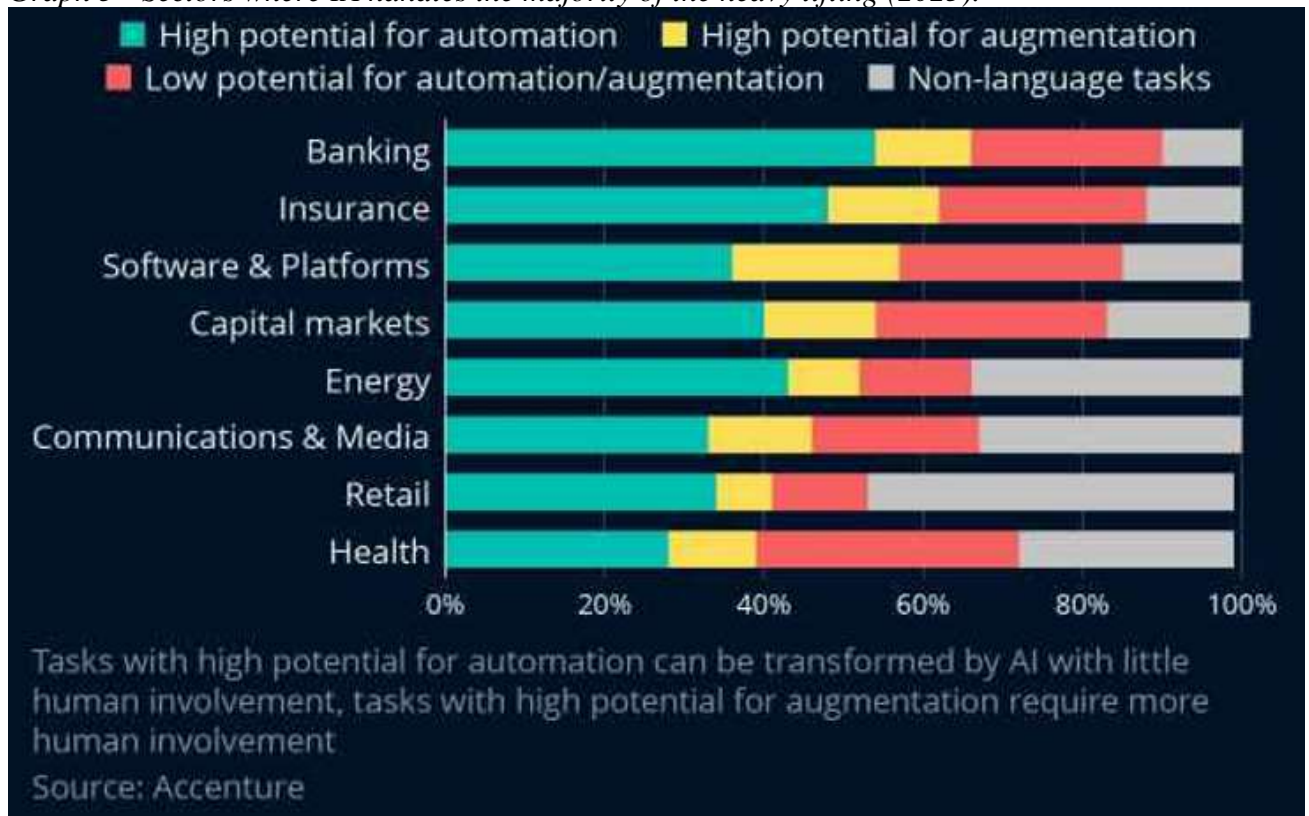
Potential Uses for AI



Sources: CompTIA

The "Potential Uses for AI" (CompTia, 2022) graph highlights the various applications of artificial intelligence. The top application is improving workflow, with 52% of respondents identifying it as a key area. AI can streamline processes, automate repetitive tasks, and optimize workflows, enhancing efficiency and freeing up human resources for strategic initiatives. It is also crucial for analyzing large datasets, revealing patterns and trends that might be impossible to detect manually. AI can improve customer experience by enhancing interactions through personalization and faster response times. It can also enhance security by continuously monitoring systems for unusual activities and identifying potential threats. It can also handle routine tasks, automating IT infrastructure, and automating IoT implementation. Overall, AI's potential applications are vast and varied, promising significant advancements in business operations and technology.

Graph 5 - Sectors where IA handles the majority of the heavy lifting (2023).



Sources: Statista 2023

The graph provides an in-depth look at how AI can change different businesses by augmenting or automating distinct functions. It classifies tasks into four categories: high potential for automation, high potential for augmentation, low potential for automation/augmentation, and non-language tasks. These categories are based on the tasks' ability to be altered by AI (Richter, 2023).

Jobs with a high potential for augmentation (yellow): those where humans can be assisted by AI to improve their capabilities without being fully automated.

Low Prospect for Automation/Augmentation (Red): Owing to their complexity or requirement for human intervention, these tasks are less likely to be affected by AI.

Non-language Tasks (Gray): Tasks that do not involve language processing, which can vary in their potential for automation or augmentation.

The financial industry, which includes insurance and banking, strongly argues for change driven by AI. Banking processes are ideal candidates for automation due to their frequently repetitive and data-intensive nature. AI systems are capable of handling routine activities like fraud detection, transaction processing, and compliance checks with efficiency. Furthermore, AI has the potential to greatly enhance human abilities in fields like customer relationship management, investment advisory, and credit risk assessment. In a similar vein, AI-driven automation of underwriting and claims processing will help the insurance sector. Beyond these standard tasks, artificial intelligence (AI) can offer insightful information on risk evaluation, fraud protection, and customised customer care.

The development and application of AI are accelerated by the software and platform industries. Therefore, it should come as no surprise that this industry has a high degree of automation, especially when it comes to software creation, testing, and maintenance. Artificial intelligence (AI) can handle repetitive coding jobs, freeing up human developers to concentrate on more complex issues and creative solutions. The finance markets, which are closely linked to technology, have great promise for integrating AI. This technology is particularly useful in the fields of regulatory compliance, portfolio management, and algorithmic trading. Though automation is common, human judgement and skill are still required due to the complexity of financial markets, which is why augmentation is a major area of interest for AI applications.

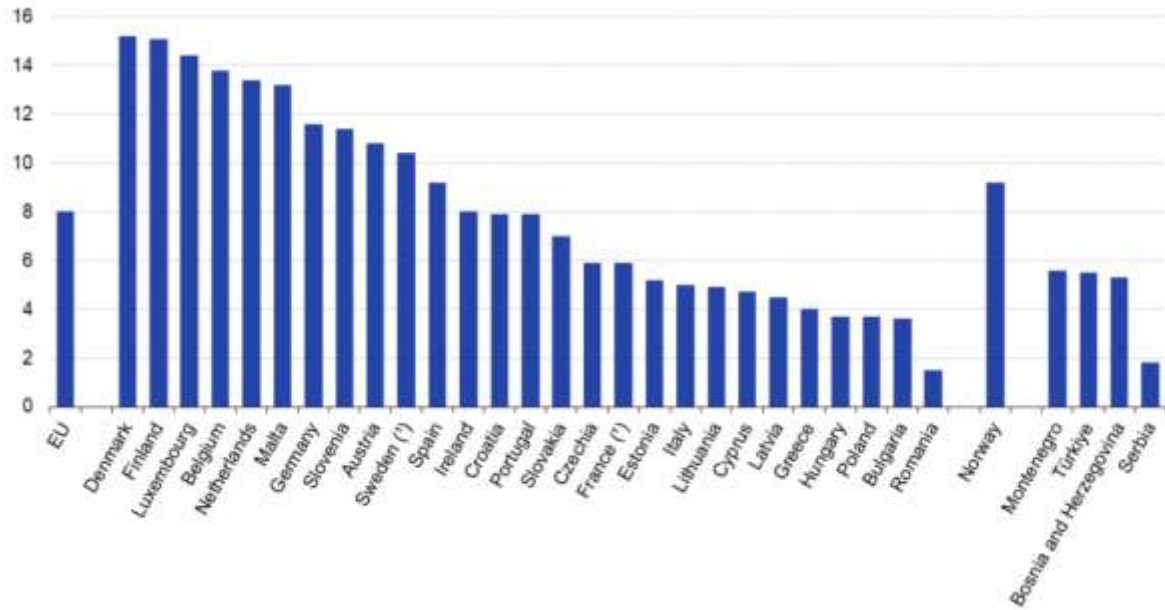
The widespread use of AI is unique in the energy sector. Although automation can enhance procedures such as equipment maintenance and grid management, the industry's dependence on intricate systems and physical infrastructure necessitates a cautious equilibrium between automation and human supervision. AI-powered

predictive analytics and optimization can greatly enhance grid dependability and energy efficiency through augmentation.

The media and communications sector presents a conflicting image. Automation faces difficulties when it comes to content generation, which is frequently linked to human creativity. AI, however, has the potential to greatly improve customer interaction, personalization, and content delivery. On the other hand, AI technologies are being quickly adopted by the retail industry. Pricing, customer service, and inventory management are all more automated. The customer experience is changing thanks to recommendation and personalization algorithms powered by AI.

Finally, the healthcare sector poses a challenging setting for the application of AI. Despite the enormous potential that AI holds to enhance patient care, medication discovery, and diagnostics, the vital nature of healthcare necessitates a high level of human oversight. Automation is restricted to certain, well-defined tasks, like administrative procedures and medical image analysis. But AI has enormous potential to complement human knowledge in domains like clinical decision support, patient monitoring, and treatment planning.

Graph 6- Number of IA utilized on European firms across European countries



Sources: (Eurostat, 2023)

This graph illustrates the utilization of different Levels of Artificial Intelligence (IA) technologies among European firms across various countries. We can see a division of country in three categories:

- **High Utilization Countries:** like Belgium, Finland, Malta and Denmark show higher percentages across all categories, indicating that enterprises in these countries are more involved with IA technologies.
- **Moderate Utilization Countries:** Countries such as Germany, Spain, and Slovakia show moderate utilization of IA technologies.
- **Low Utilization Countries:** The majority of countries like Italy, France, Poland and Romania have lower percentages across all categories, suggesting that enterprises in these countries are less engaged with IA technologies.

The information we've gathered reveals a significant trend: artificial intelligence (AI) is increasingly shaping both national economies and global businesses. Over the past few

years, AI has evolved from a niche technology to a driving force in various industries. This shift has led to the creation of new job opportunities, particularly in tech-driven fields like data analysis, machine learning, and robotics. However, the rise of AI has also resulted in the displacement of certain jobs, particularly those involving routine or manual tasks that can be more efficiently performed by machines. As AI continues to advance, its impact on the workforce and economic structures will likely deepen, prompting both challenges and opportunities for adaptation.

3.2 Automation and Robotics: advancements in automation and robotics and their potential impact on job categories

With significant advancements in vision, speech, and prediction capabilities, robots have evolved beyond automating simple routine tasks to performing more cognitively complex work and tasks requiring specific manual dexterity. Industrial robots are defined by the International Federation of Robotics (IFR) as reprogrammable, multipurpose manipulators with at least three axes that are autonomously controlled and are mostly utilised in industrial automation applications. These robots can perform a wide range of tasks, such as material handling, assembling, welding, painting, packaging, picking, and placing. By minimising human error, they can dramatically reduce production quality variance (Marina Bill, 2023).

Robots has a competitive advantage over human labour in two main areas:

- Firstly, in tasks requiring physical manipulation, robots excel in following complex multistep protocols with high precision, enhancing consistency and efficiency in production processes. For instance, in electronics assembly, where components consist of numerous plastic and metal parts, robots can substantially reduce product defect rates. Similarly, in the automotive industry, robots can install and weld parts onto car bodies with remarkable accuracy. In healthcare and pharmaceuticals, robots can meticulously prepare materials and analyze samples, minimizing errors and human exposure to hazardous substances. Furthermore, a variety of warehousing logistics have been automated by robots, effectively moving items between locations without the need for human participation.
- Secondly, robots exhibit superior manual dexterity in performing specific tasks compared to humans. Although they lack the versatility of human hands, robots can be

trained to execute certain tasks more effectively and sometimes surpass human capabilities. In warehouse settings, robots can manage physical inventory, relieving humans from lifting and handling cumbersome, heavy objects, thus reducing worker injuries and delivery times. In manufacturing, robots can perform highly intricate tasks involving complex manual manipulations, such as 360-degree multi-arm rotations with numerous repetitions. These tasks are executed with precision and consistency over long durations, substantially mitigating human errors caused by fatigue and the manipulation of production quotas (Jay Dixon B. H., 2021).

Research examining the effect of robots on employment is still nascent, with only a few studies examining the substitutability between robots and labor. However, preliminary data to date indicates that the introduction of robots would likely result in severe labour displacement.

For example, 47% of all jobs in the United States may be displaced. Breaking each occupation into a set of concrete tasks, Organisation for Economic Co-operation and Development researchers find that 70% of tasks performed by labor could be automated, leading to both labor displacement and wage reductions (Restrepo, 2017). Authors like Acemoglu and Restrepo find that one robot can replace around six human workers using a measure of robot penetration at the industry level in the United States. Using similar data, also find that robot adoption is associated with a reduction in hours worked for low-skilled labor.

However, historical precedents like General Purpose Technologies (GPTs) offer a contrasting perspective. Researchers observed instances where GPTs increased employment alongside productivity, suggesting that labor's share of production might

ultimately remain constant. Robots could potentially have a positive impact on employment through several mechanisms (Richard G. Lipsey, 2016):

- **Increased Demand for Non-Automated Services:** Productivity gains from automation can lead to a rise in demand for goods and services that require human input, potentially creating new jobs in these sectors.
- **Capital Deepening and Efficiency:** As robot technology advances, capital deepening can further boost robot effectiveness and productivity. This, in turn, could lead to economic growth without necessarily displacing workers.
- **Complementary Jobs:** Automation can create new jobs or increase demand for existing tasks that complement robot capabilities. Human skills in areas like programming, maintenance, and oversight will become increasingly valuable.

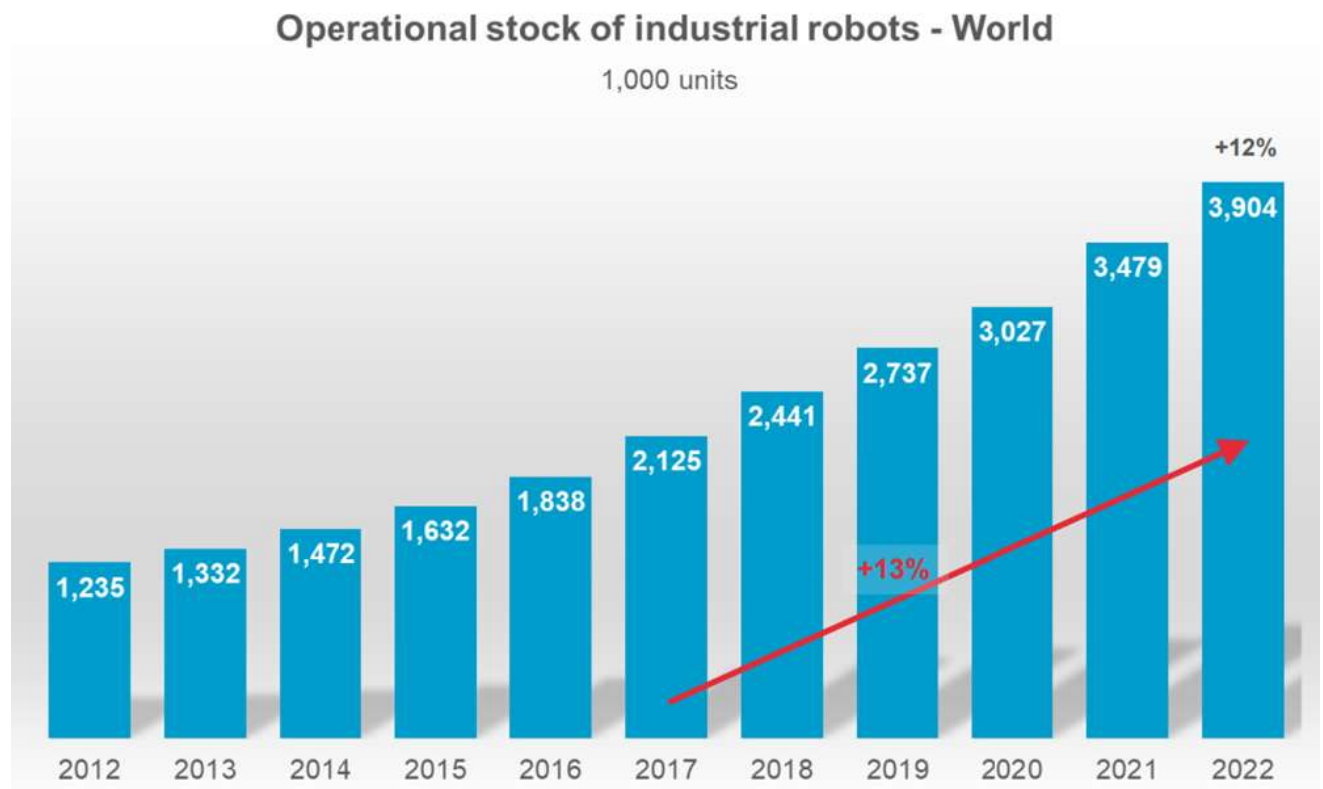
By analysing what has been said so far, we can assume that robots may displace low-skilled workers and often create new opportunities for high-skilled workers who can manage, program, and maintain these robotic systems. This bifurcation in the labor market suggests that the overall impact on employment is complex and multifaceted, requiring a deeper understanding of how robots interact with various job functions and skill levels.

The integration of robotics into the workforce not only affects employment but also raises significant questions about the future of work. This necessitates the development of policies that facilitate workforce transitions and address potential job displacement. Such policies may include funding education and training initiatives to equip workers with the necessary skills for an increasingly automated industry, as well as providing social safety nets for those impacted by technological advancements. As the nature of work continues to evolve due to robotics breakthroughs, ongoing research and policy

interventions will be crucial in shaping a future that maximizes the benefits of automation while minimizing its drawbacks.

The graphs provide further insight into these trends:

Graph 7 – Operational stock of industrial robots – world
Almost 4 million industrial robots operating around the world



Source: World Robotics 2023

The graph depicts the global stock of operational industrial robots since 2012, according to the World Robotics 2023 report by the International Federation of Robotics (IFR). It shows a clear and consistent upward trend, indicating a rapid increase in the number of industrial robots deployed worldwide.

This exponential growth signifies a significant acceleration in automation across industries. As the graph suggests, the number of operational industrial robots has nearly doubled in the past decade, jumping from roughly 1.2 million units in 2012 to almost 4 million units in 2022. This surge reflects the increasing affordability, versatility, and

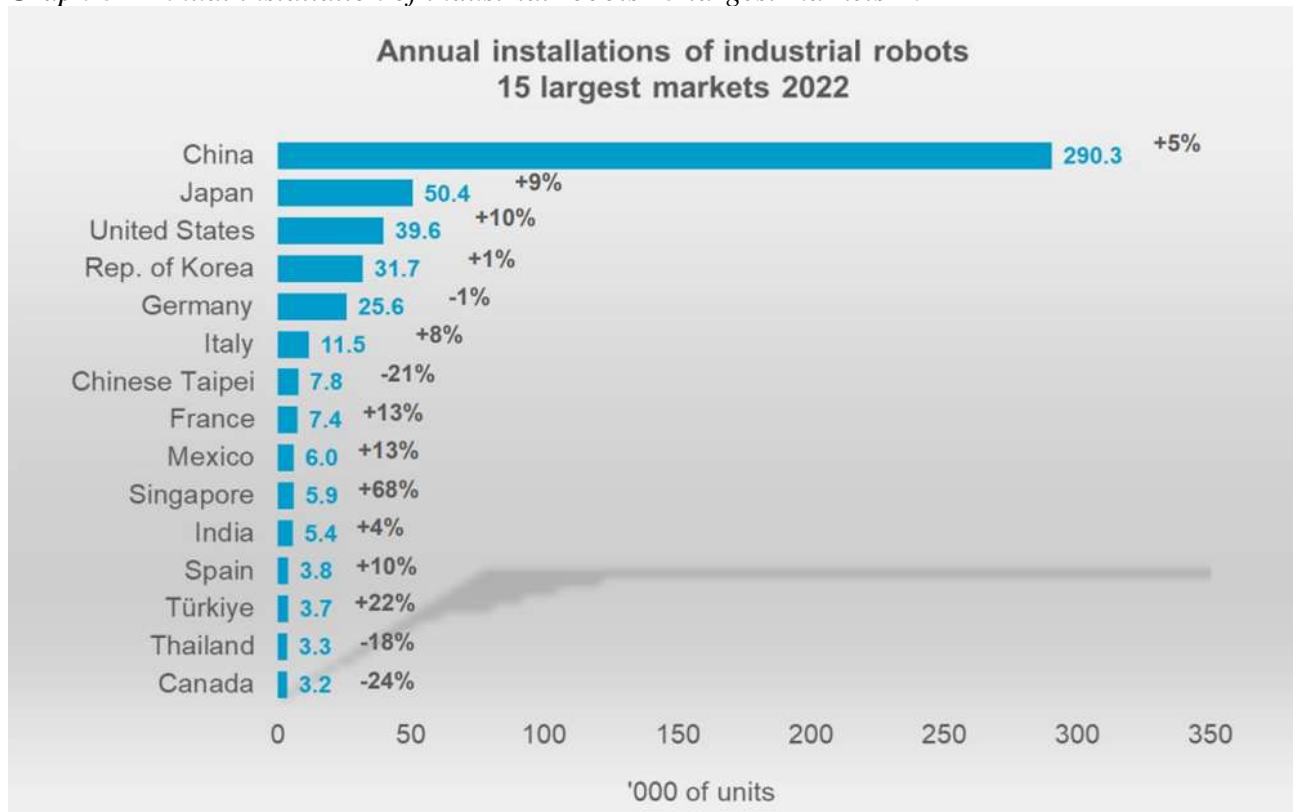
sophistication of robotic systems, making them a more attractive option for manufacturers and businesses across the globe.

This rise in automation presents a double-edged sword. On the one hand, it represents a surge in productivity and efficiency. Robots can perform tasks with greater precision, speed, and consistency than humans, leading to increased output and potentially lower production costs. This can contribute to economic growth and industrial competitiveness.

On the other hand, the expanding presence of robots also raises concerns about job displacement. As robots take over tasks traditionally performed by human workers, particularly those involving repetitive manual labor, there is a risk of significant job losses, particularly for low-skilled workers. The graph doesn't depict this displacement directly, but the correlation between rising robot adoption and potential job losses is a major point of discussion and research.

The trend of automation is likely to continue, with the graph likely to show a further increase in operational robots in the coming years. This suggests a potential bifurcation in the labor market, as highlighted earlier. While some jobs may be lost to automation, new opportunities will emerge in areas like robot design, maintenance, programming, and data analysis. These jobs will require a higher skillset, creating a demand for a more technically proficient workforce.

Graph 8— Annual installation of industrial robots 15 largest markets 2022

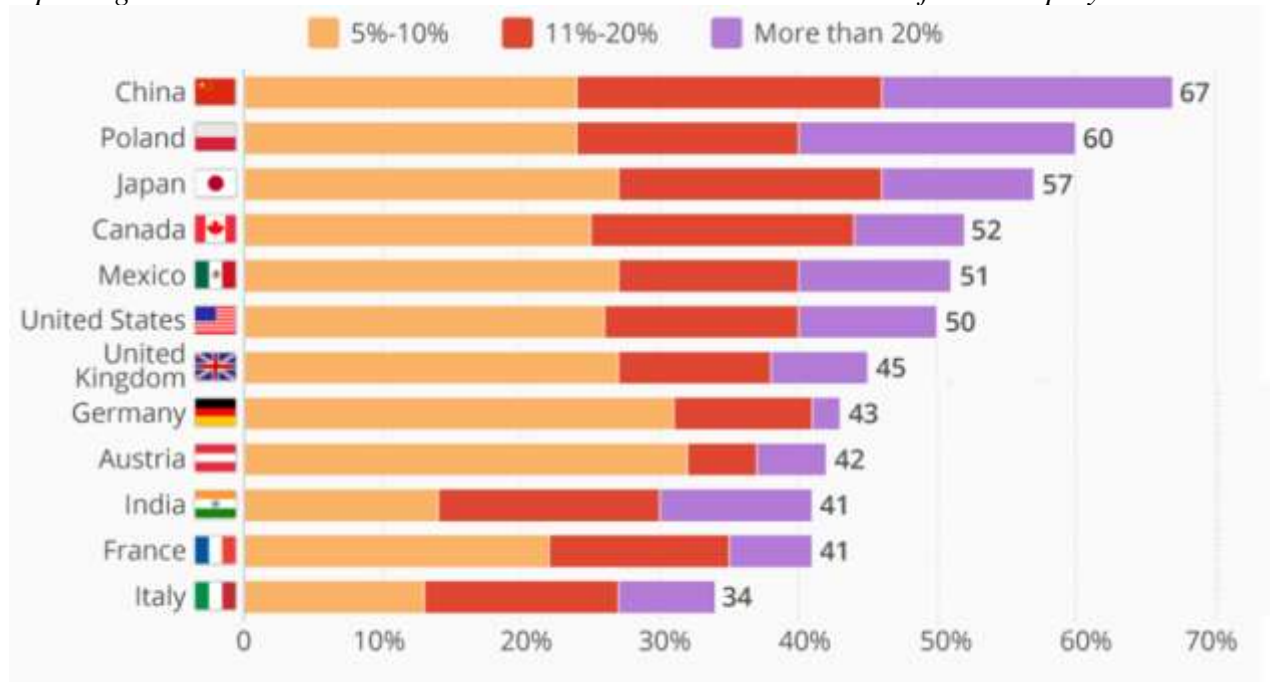


Sources: World Robotics 2023

The graph you sent depicts the annual installations of industrial robots in the 15 largest markets in 2022, according to the World Robotics 2023 report by the International Federation of Robotics (IFR). It highlights China's dominance in robot adoption, with a significant lead over other countries.

While China is the frontrunner, the graph also reveals a broader trend of automation across the globe. All 15 of the countries listed have seen a rise in robot installations, indicating a growing acceptance and integration of robotic systems in various industries. This trend is likely driven by factors like increasing affordability and sophistication of robots, alongside the potential for productivity gains and cost reductions.

Graph 9- How Advanced Robotics Will Impact Job Markets - Share of companies expecting a reduction in the number of employees



Sources: Statista

The graph "How Advanced Robotics Will Impact Job Markets, Share of companies expecting a reduction in the number of employees" shows the anticipated effects of advanced robotics on employment across various countries. China leads the chart with 67% of companies anticipating a significant reduction in the number of employees, with a notable portion expecting reductions greater than 20%. Poland follows closely with 60% of companies expecting workforce reductions, while Japan is next with 57%. Canada and Mexico have 52% and 51% of companies expecting reductions, respectively. The United States has 50% of companies predicting workforce reductions due to robotics, while the United Kingdom and Germany have 45% and 43% of companies. Austria, India, and France have similar expectations, with a significant portion expecting reductions greater than 20%. Italy is at the lower end, with 34% of companies expecting workforce reductions. This indicates a relatively lower expectation of robotics impacting employment compared to other countries. Overall, the graph

highlights a global trend towards adopting advanced robotics, with varying degrees of expected impact on job markets. Countries with higher percentages indicate a stronger move towards automation, potentially leading to significant workforce reductions. This trend underscores the need for strategies to manage the transition, such as reskilling and upskilling programs, to mitigate the impact on employment (McCarthy, 2022).

Figure 10 - The Countries with the Highest Density of Robot Workers; number of installed robot per 10,000 employees in the manufacturing industry



Sources: Statista

The Figure "The Countries With the Highest Density of Robot Workers" shows the rapid adoption of robotics in the manufacturing industry. A robotic arm is shown in the drawing on the right side of the above figure, signifying the idea of robotics and industrial automation in the manufacturing industry. This kind of robotic arm is frequently linked to automation in sectors where robots

execute precise or repetitive operations, like the automotive, electronics, and heavy machinery production industries.

South Korea leads the chart with a significant increase from 710 robots per 10,000 employees in 2017 to 1,012 in 2022. Germany follows with a jump from 322 robots in 2017 to 415 in 2022, driven by its robust industrial base. Japan also shows steady growth, moving from 308 robots in 2017 to 397 in 2022. China shows the most dramatic increase, from 97 robots in 2017 to 392 in 2022, driven by rapid industrialization and investments in automation. Sweden and Switzerland show significant but less dramatic increases, driven by advanced manufacturing sectors. The United States has the highest robot density, driven by productivity enhancement in various sectors. Italy and Canada show moderate increases, with Italy moving from 190 to 219 robots and Canada from 161 to 198. These countries are gradually integrating more robotics to improve manufacturing efficiency and maintain competitiveness in the global market. The worldwide average of 151 robots per 10,000 employees in 2022 serves as a benchmark, highlighting the advanced state of automation in the countries listed above, all of which exceed this global average (Fleck, 2024).

In combination with each other, these graphs show how industrial automation is continuously changing and how this is having a variety of effects on the labour market around the world. Adaptive policies and strategies to handle opportunities and challenges are becoming more and more important as robots become more commonplace. In order to prepare workers for an increasingly automated workplace, this entails funding education and training programs and offering social safety nets to individuals impacted by technological breakthroughs.

CHAPTER 4. Italian situation and positioning

It is important to pay attention to Italy's position in relation to new developments in technology, is crucial for several interconnected reasons that highlight both the opportunities and challenges presented by technological advancements:

- **Unique Industrial Landscape:** Italy's industrial landscape is unique because it is characterized by a highly developed automation sector with a considerable market share worldwide. By examining Italy's experience, we can gain valuable insights into how a country with deep industrial roots and sector-specific strengths integrates new technologies like robotics and AI. This focus allows us to understand how these advancements are shaping not just the Italian economy, but also influencing global markets, offering lessons on leveraging traditional strengths in the face of modern technological shifts.

- **Effect on Workplace Employment:** The intersection of technological innovation and employment is a critical area of focus when discussing Italy. As new technologies emerge, they inevitably lead to a reshaping of the labor market, creating new opportunities while also posing risks of job displacement. The labor market will always change as a result of new technologies, offering both opportunities and threats for employment displacement. The experience of Italy offers a complex perspective on this dynamic. There are useful lessons to be learnt from the nation's strategy for striking a balance between the growth of jobs and the possible automation-related loss of jobs. By focusing on Italy, we can explore how targeted initiatives, such as reskilling and upskilling programs, are being employed to help the workforce adapt to these changes, ensuring that technological progress does not come at the expense of workers' livelihoods.

- Economic and Social Policy Insights: Italy's journey through the adoption of new technologies offers a rich case study in economic and social policy development. As Italy integrates AI and automation into its economy, the policies it implements to manage these changes become crucial. A focus on Italy allows us to explore how effective policies can be designed to promote economic growth while safeguarding workers' rights and well-being.

- Future Trends and Opportunities: Italy's current trajectory in embracing new technologies provides a lens through which we can anticipate future trends in automation and AI. This forward-looking perspective is crucial for policymakers, business leaders, and educators as they prepare for the continued evolution of the digital age.

- Cultural and Economic Resilience: Lastly, Italy's approach to integrating new technologies while preserving cultural and economic resilience is particularly instructive. The way Italy manages worker substitutability—ensuring that technological change does not undermine worker well-being—is a critical aspect of this focus.

Focusing on Italy's situation in the context of new technologies and worker substitutability provides a comprehensive understanding of how a major European economy is navigating the complexities of technological change. This analysis not only offers insights specific to Italy but also serves as a model for other nations grappling with similar challenges, providing a roadmap for successfully integrating new technologies while protecting the workforce and ensuring sustainable economic growth.

4.1 Italian robotics

Analyzing the Italian situation in the “*Graph 8*” we found out that Italy is the 6th country in the world with the highest number of robotic installations, follows with a market share of 16% within the EU: installations grew by 8% respect the previous year.

Also analyzing the “*Graph 7*” we found out that the proportion of jobs in various countries that are susceptible to automation, divided into categories of risk. Italy shows that about 34% of its workforce faces more than a 20% chance of automation, while the rest have lower probabilities.

Risk of Automation in Italy: workforce is at a lower risk of automation (in the "more than 20%" category) compared to countries like China (67%), Poland (60%), and Japan (57%). However, Italy still faces significant challenges with a noticeable portion of its workforce being vulnerable to automation.

While not at the forefront of robot installations, Italy boasts a robust and established automation industry. According to (Robotics, 2022), Italy is a leader in providing and adopting robotics and automation solutions. This strength lies in its large and mature automation industry, particularly within the packaging machinery sector, where Italy holds the highest global market share at 16.5%.

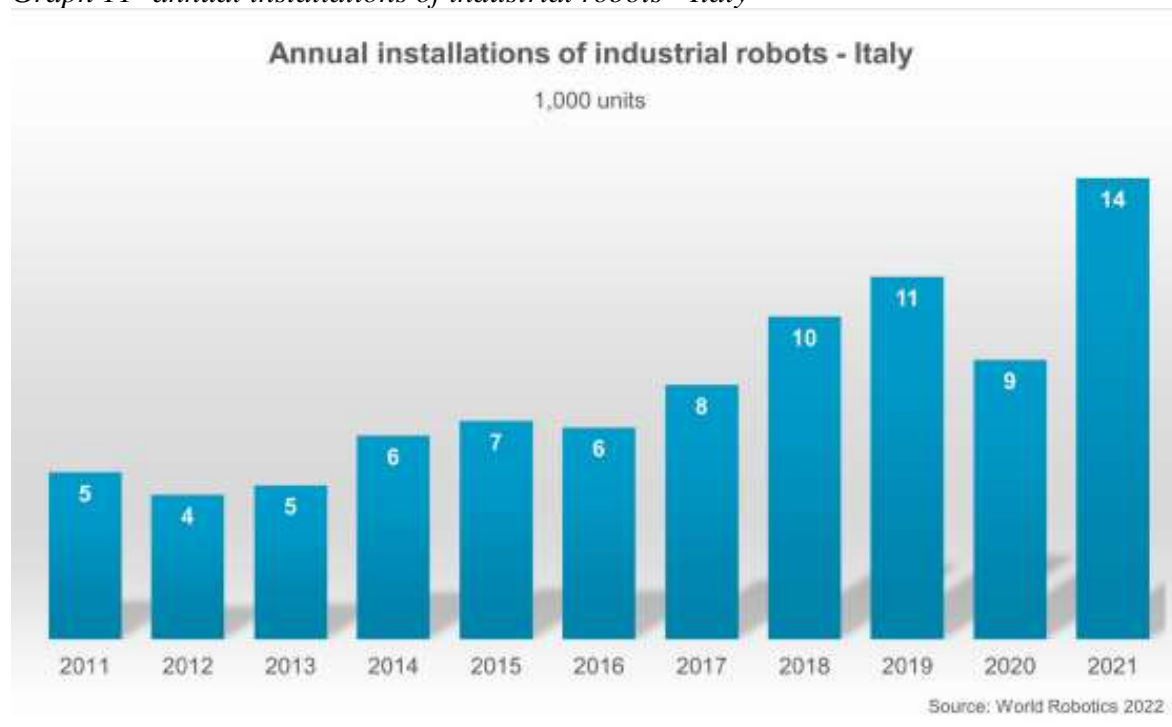
Graph 6 suggests that Italy could benefit from increasing its robotics density to stay competitive globally. Investing in automation could help Italian industries improve productivity and maintain competitiveness.

One of the biggest challenges for Italy firms and economy is Balancing Automation and Workforce Transition: While Italy's workforce faces a moderate risk of automation, there is a need for strategic planning to retrain workers and manage the transition to

more automated industries. This includes focusing on education and skill development in areas less likely to be automated, such as advanced manufacturing, robotics maintenance, and software development. Furthermore Italy should have a

Sectoral Focus: focusing on sectors where automation is likely to have the most significant impact, such as manufacturing and logistics, to prepare for future disruptions and capitalize on opportunities that automation may bring.

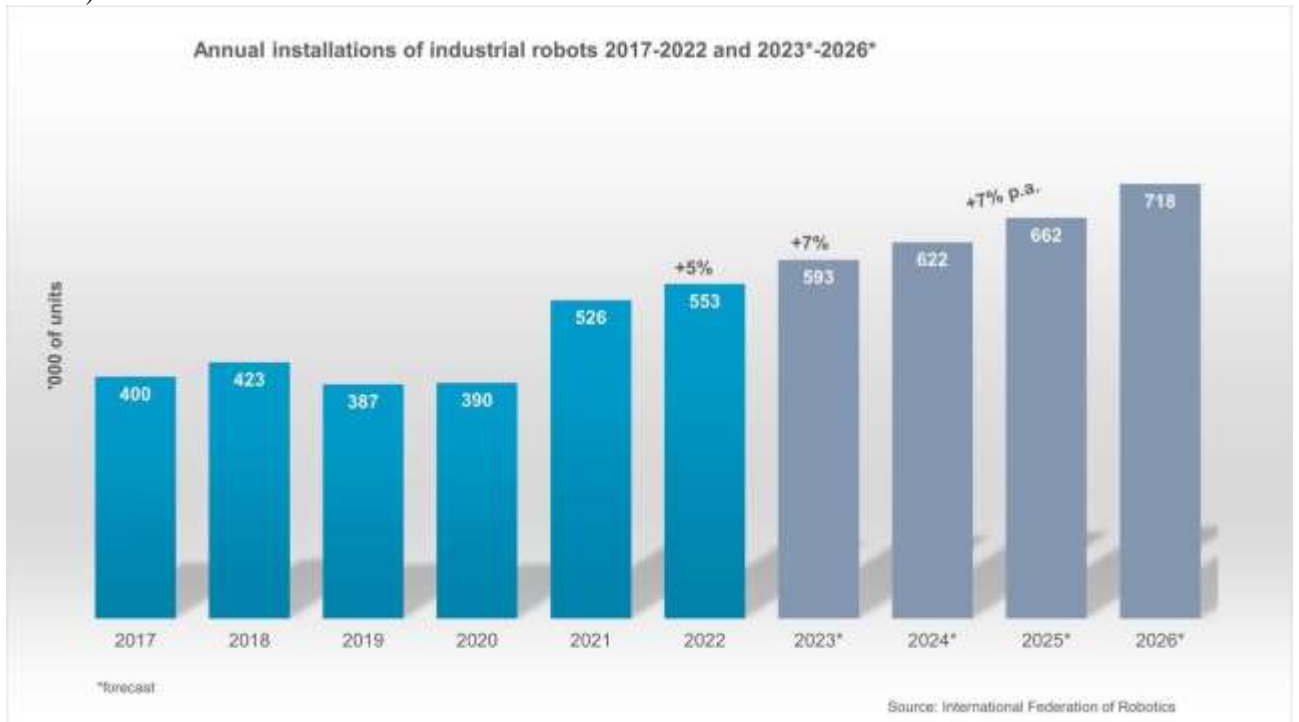
Graph 11- annual installations of industrial robots - Italy



Source: World Robotics 2022

The graph reveals a gradual increase in robot installations in Italy over the past decade. it signifies a rising adoption of automation within Italian industries. This aligns with the information that Italy has a well-established automation industry, particularly strong in packaging machinery (Heer, 2022).

Graph 12- annual installation of industrial robots worldwide (2017-2022 and 2023* - 2026*)



Source: International Federation of robotics 2023

The graph shows the annual installations of industrial robots globally with data from 2017 to 2022 and with a forecast for 2023 to 2026.

The data shows a general upward trend in the number of industrial robots installed each year. The forecast for the years 2023 to 2026 predicts a continued increase in installations, with a compound annual growth rate of 7%.

The graph also includes a lines indicating the average annual growth rate for the period 2017 to 2022, which is 5%. This suggests that the growth rate is expected to accelerate in the coming years (Heer, 2022).

Now doing some calculations with the two-graph analyzed above we can do a forecast of Italian robots installation for the years 2023 to 2026 (given that the official 2023 data is still pending, I have provided a forecast to offer a preliminary estimate), Utilise the percentage forecasted in the “Graph 12”.

Steps to Forecast Italy's Future Data:

From 2017 to 2021, Italy saw significant growth from 8,000 units to 14,000 units, indicating robust growth. Let's calculate the annual growth rate during this period.

The compound annual growth rate (CAGR) for 2018–2021 can be calculated using the formula:

$$\text{CAGR} = (\text{End value}/\text{Start value})^{1/n} - 1$$

where:

- End Value = 14 (thousands of units in 2022)
- Start Value = 10 (thousands of units in 2018)
- $n = 3$ years

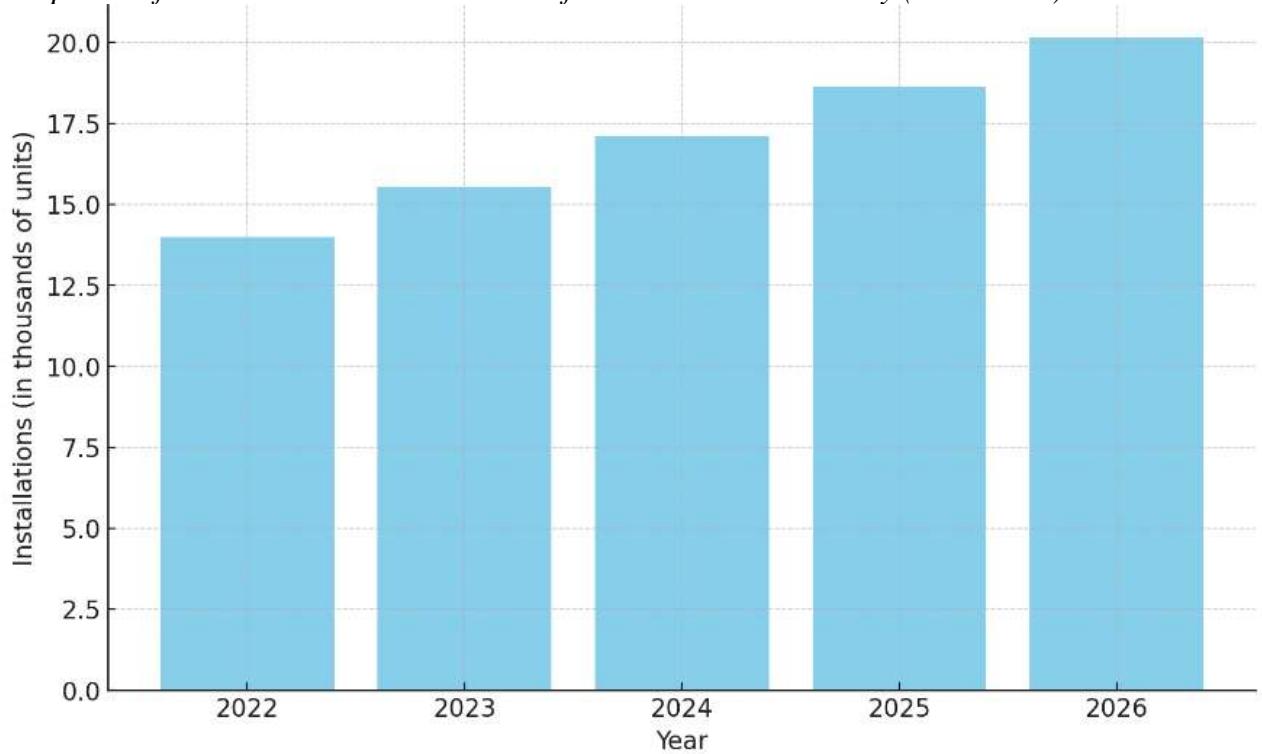
$$\text{CAGR} = (14/10)^{1/3} - 1 \approx 11.96\%$$

apply Global Trends to Italy's Growth Rate:

- Italy's growth rate (12%) is higher than the global forecast growth rate (5-7%).
- To forecast Italy's future, let's adjust the global forecast growth rates by considering Italy's higher growth trend.
- If the global forecast suggests a 7% growth, for instance, we might assume that Italy could continue to outpace this slightly, perhaps maintaining or slightly reducing from its historical 12% rate.

Assuming a stable market environment without unforeseen disruptions like pandemics or conflicts, we anticipate:

Graph 13 – forecasted annual installation of industrial robots in Italy (2022-2026)



Sources: *International Federation of robotics 2023*¹

The Italian market will be significantly impacted by the anticipated rise in industrial robot installations, especially in light of automation, productivity, and the possibility of replacing human labour with robots.

The ongoing increase in robot installations indicates that automation is becoming more and more important to Italian companies as a means of enhancing productivity. Robots are able to perform more productively and consistently because they are more accurate, rapid, and fatigue-free.

Italian businesses can maintain their competitiveness in the international market by embracing automation. Manufacturing, electronics, and automotive industries stand to gain the most from robotic automation's enhanced productivity and cost reductions. As industries increasingly automate tasks, certain jobs that involve repetitive, manual, or

¹ “*ns graph RI-elaboration of Daniele Marconi*”

dangerous work might be at higher risk of being replaced by robots. This trend could lead to a reduction in demand for low-skilled labor in specific sectors.

While some jobs may be displaced, the demand for workers with skills in robotics, programming, and maintenance of automated systems will likely rise. Workers may need to upskill or reskill to remain competitive in the job market, focusing on roles that involve complex decision-making, creativity, and human interaction, which are less susceptible to automation. The increasing adoption of robotics could spur further innovation within Italy's industrial sector. Companies might invest in advanced robotics and AI technologies, leading to the development of new products, services, and business models. This innovation could help Italy maintain its position in global value chains, particularly in high-tech manufacturing.

There could be a widening gap between workers with high-demand skills and those whose jobs are more easily automated. This disparity might lead to socioeconomic challenges, such as income inequality and the need for social safety nets.

The nature of work might shift, with more emphasis on human-robot collaboration. Workers may increasingly operate alongside robots, using their unique human capabilities to complement automated processes. The Italian government and industry stakeholders may need to consider policies that support workers through this transition. This could include investing in education and training programs, providing support for displaced workers, and ensuring that the benefits of automation are broadly shared across society (Carucci, 2023).

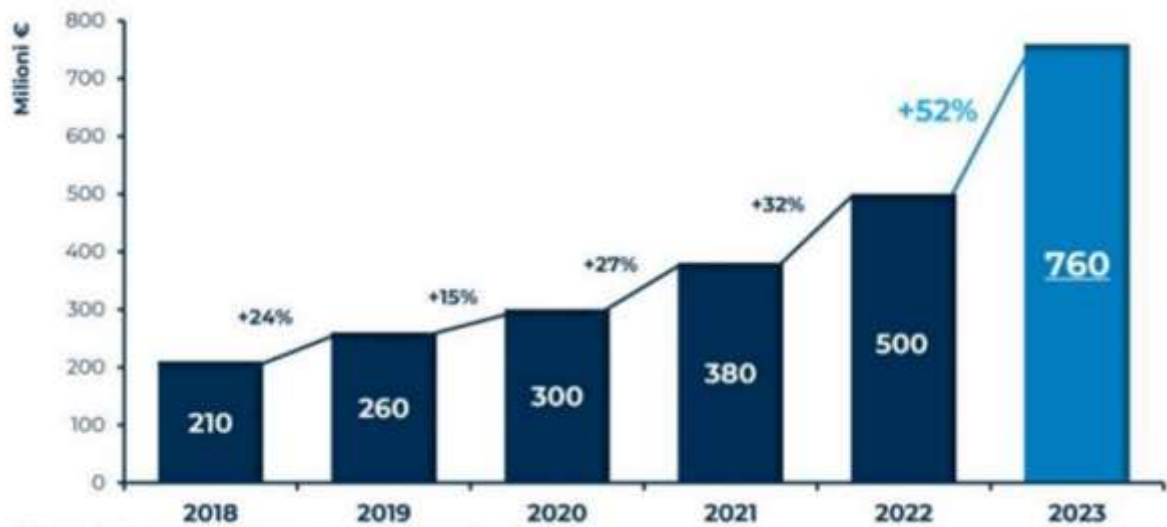
4.2 Italian Artificial Intelligence

By looking at the “*Graph 6*” and focusing on Italian situation we can see that: Italy is categorized as a moderate adopter of AI, meaning that although it is not at the forefront of the technology, it is actively utilizing it. In industries where artificial intelligence (AI) can improve efficiency, streamline supply chains, and create novel product offers, such as manufacturing, automotive, and fashion, this is essential to preserving competitiveness.

Furthermore, it can catch up other countries by boosting its investments in AI research, development, and implementation, since higher AI utilization is observed in nations like Belgium, Finland, and Austria. Increasing the use of AI could strengthen Italy's economy and position it better in the international market. As AI adoption in Italy continues to grow, the country is likely to see a dual impact on its workforce. On one hand, there will be job creation in fields such as AI development, data science, machine learning, and robotics. On the other hand, certain jobs, particularly those involving routine tasks, may be displaced as AI technologies take over these roles.

To mitigate job displacement, Italy will need to focus on education and reskilling programs that prepare workers for the changing job market. Emphasizing digital literacy, technical skills, and AI-related knowledge will be critical in ensuring that the workforce can adapt to new roles created by AI advancements.

Graph 13 - IA market till today in Italy 2024



Source: Politecnico di Milano & Osservatori

The graph illustrates the growth of Italian artificial intelligence market, showcasing a remarkable growth from €210 million in 2018 to €760 million in 2023. This surge is driven by factors such as heightened demand for AI solutions, the expanding adoption of machine learning and deep learning technologies, and technological advancements.

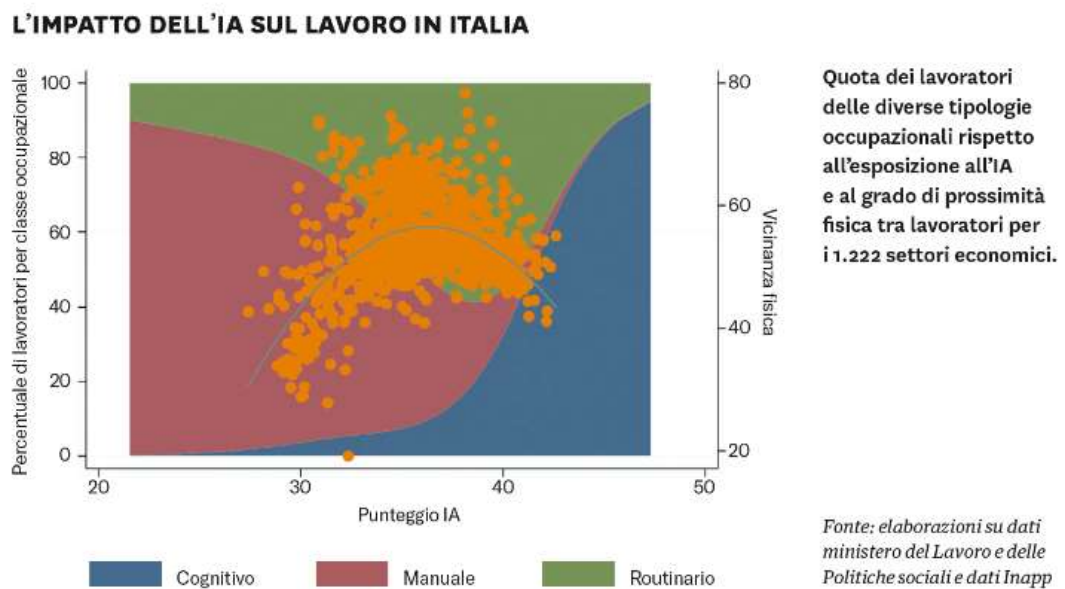
A particularly noteworthy period of growth occurred between 2022 and 2023, with a significant increase of 52%. This trend is indicative of the market's rapid maturation and increasing investment in AI capabilities.

The rapid growth of the AI market in Italy, as evidenced by the graph, has significant implications for worker substitutability. As AI technologies become more sophisticated and capable, they can increasingly automate tasks previously performed by human workers (Balabio, 2024).

4.3 Workers displacement in Italy

The workforce is faced with a significant problem as a result of the rapidly changing fields of robotics and artificial intelligence (AI), which will have differing effects on different job types and educational levels. The following graphs and research highlight the industries and educational backgrounds that are most susceptible to automation, delving into the subtleties of how they affect job displacement in Italy.

Figure 14 - impact of IA on the Italian work (2022)



Sources: Harvard Business review

The Figure provides a nuanced visualization of how artificial intelligence (AI) affects different types of jobs in Italy. It specifically examines the percentage of workers across three occupational classes—cognitive, manual, and routine—relative to their exposure to AI and the degree of physical proximity required in their jobs.

On the x-axis, we see the AI Score, which ranges from 20 to 50. This score likely represents the degree to which AI is integrated into or impacts various jobs. The y-axis on the left measures the percentage of workers within each occupational class, from 0%

to 100%, while the y-axis on the right measure's physical proximity, ranging from 0 to 80. Physical proximity here refers to how close workers need to be to one another to perform their tasks, which is an important factor in understanding job vulnerability and adaptability in the context of AI integration (Bentivogli, 2022).

The graph is divided into three color-coded regions representing different occupational classes:

- **Cognitivo (Cognitive)** jobs are shown in blue. These jobs typically involve tasks that require significant intellectual engagement, problem-solving, and decision-making.
- **Manuale (Manual)** jobs, depicted in red, involve physical labor or hands-on tasks.
- **Routinario (Routine)** jobs are illustrated in green, representing occupations that involve repetitive tasks and procedures.

The orange dots scattered across the graph represent individual data points, indicating the distribution of workers according to their AI score and physical proximity.

From the visualization, several key insights emerge:

1. **Cognitive Jobs:** These are concentrated towards the lower end of the AI score spectrum. This suggests that jobs requiring cognitive skills are currently less exposed to AI impacts. The implication is that these roles either incorporate AI in supportive ways without significant displacement of human labor or that AI technology has not yet advanced to a point where it can replace complex cognitive tasks effectively.
2. **Manual Jobs:** These jobs span a wide range of AI scores and physical proximity. This distribution indicates a varied impact of AI on manual labor, likely because some manual tasks are more susceptible to automation than others. For

instance, tasks that involve straightforward, repetitive physical actions may be more easily automated, while those requiring dexterity or situational judgment may still rely heavily on human labor.

3. **Routine Jobs:** These are more prevalent at higher AI scores, indicating a greater susceptibility to automation. Routine jobs, by their nature, involve repetitive tasks that can be more easily codified and performed by AI systems. This trend underscores the vulnerability of routine occupations to AI, as these jobs are prime candidates for automation.

The right y-axis showing physical proximity adds another layer of analysis. Jobs requiring higher physical proximity may be less likely to be automated not just because of technological limitations but also due to social and practical considerations in the workplace.

Overall, the graph illustrates a complex landscape where AI's impact on the workforce varies significantly across different types of jobs. Cognitive jobs currently show resilience to AI disruption, manual jobs are in a transitional phase with varied susceptibility, and routine jobs are the most exposed to automation. This distribution underscores the importance for policymakers, educators, and business leaders to focus on reskilling and upskilling workers, particularly those in routine and manual occupations, to ensure a smooth transition in the evolving labor market.

The graph provides critical insights into the substitutability of workers in Italy across different occupational classes in the context of AI integration. Here's a detailed discussion on what this means for worker substitutability:

1. **Cognitive Jobs:**

- **Low AI Score:** Cognitive jobs, which involve tasks requiring significant intellectual engagement, are clustered at lower AI scores. This suggests that these jobs are currently less susceptible to substitution by AI. The complexity, decision-making, and problem-solving skills required for cognitive roles are difficult to automate with existing AI technologies. Hence, workers in cognitive occupations are less likely to be replaced by AI in the near term.

- **Implications:** These workers have a lower substitutability risk. However, there may be a need for them to increasingly integrate AI tools into their workflows to augment their capabilities rather than replace them.

2. **Manual Jobs:**

- **Broad Range of AI Scores:** Manual jobs are spread across a wide range of AI scores, indicating varied susceptibility to AI substitution. Tasks that involve repetitive physical actions are more likely to be automated, while those requiring fine motor skills, adaptability, or situational judgment may remain less affected by AI.

- **Implications:** The substitutability of workers in manual jobs is heterogeneous. Some workers may face high risks of replacement by AI, especially in sectors where automation technologies are advanced. Others, performing tasks that are more complex or context-dependent, may not be easily substituted.

3. **Routine Jobs:**

- **High AI Score:** Routine jobs, characterized by repetitive and predictable tasks, are concentrated at higher AI scores. This indicates a high susceptibility to automation, as these tasks can be efficiently handled by AI systems. Routine workers face the highest risk of substitution as AI and automation technologies improve.

- **Implications:** Workers in routine jobs have a high substitutability risk. These workers are prime candidates for displacement by AI, leading to significant changes in the labor market. It is crucial for these workers to acquire new skills and transition to roles less susceptible to automation.

4. **Physical Proximity:**

- The right y-axis showing physical proximity adds another dimension to the substitutability discussion. Jobs requiring higher physical proximity may face practical challenges in automation. For instance, roles involving direct human interaction or tasks performed in close physical quarters may remain less susceptible to AI substitution despite being routine or manual.

- **Implications:** Even within the same occupational class, jobs that require close physical proximity might have lower substitutability due to the inherent difficulties in automating tasks that involve human interaction or physical presence.

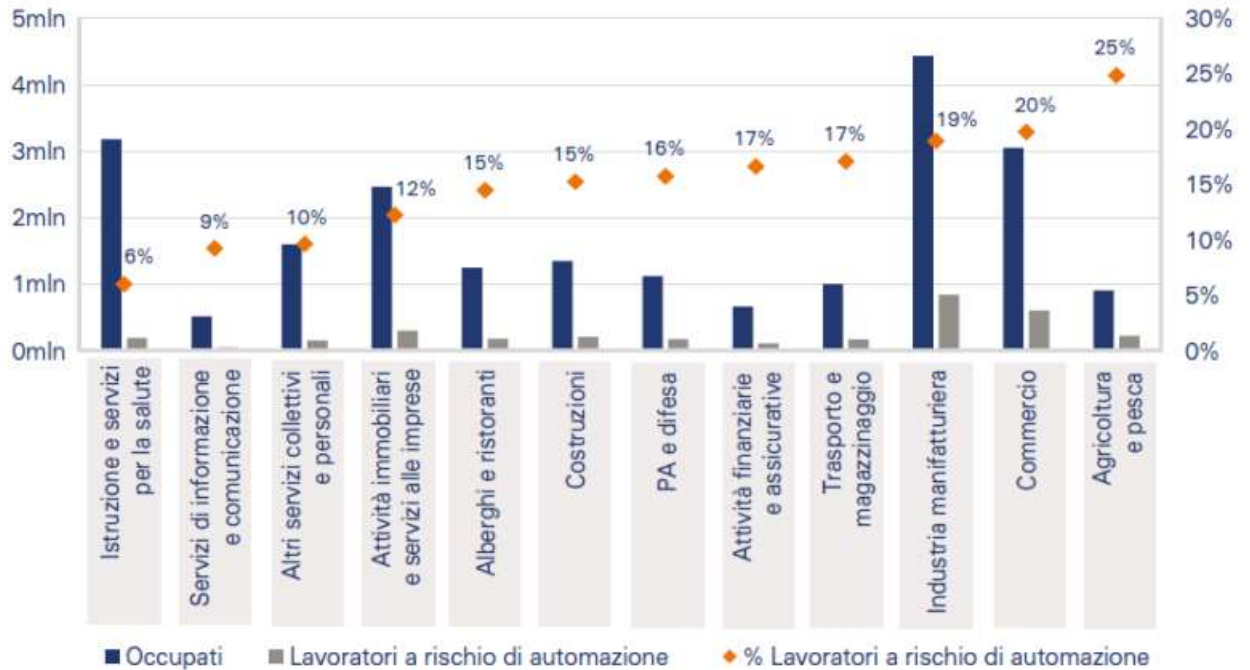
Workforce Dynamics: The graph highlights the need for targeted policies to support workers in routine and manual jobs that are at higher risk of AI substitution. Reskilling and upskilling initiatives are essential to help these workers transition to more secure employment opportunities.

Economic and Social Policy: Policymakers must consider the varied impacts of AI across different job types and design interventions that can mitigate the negative effects on workers most vulnerable to displacement. This includes investing in education and training programs tailored to the evolving job market.

Employers should focus on integrating AI in ways that augment human capabilities rather than merely replacing workers. This involves fostering a collaborative

environment where AI tools are used to enhance productivity and innovation while retaining human oversight and control.

Figure 15 - Workers at risk of Robotics and employment by sector In Italy 2019



Sources: Inapp

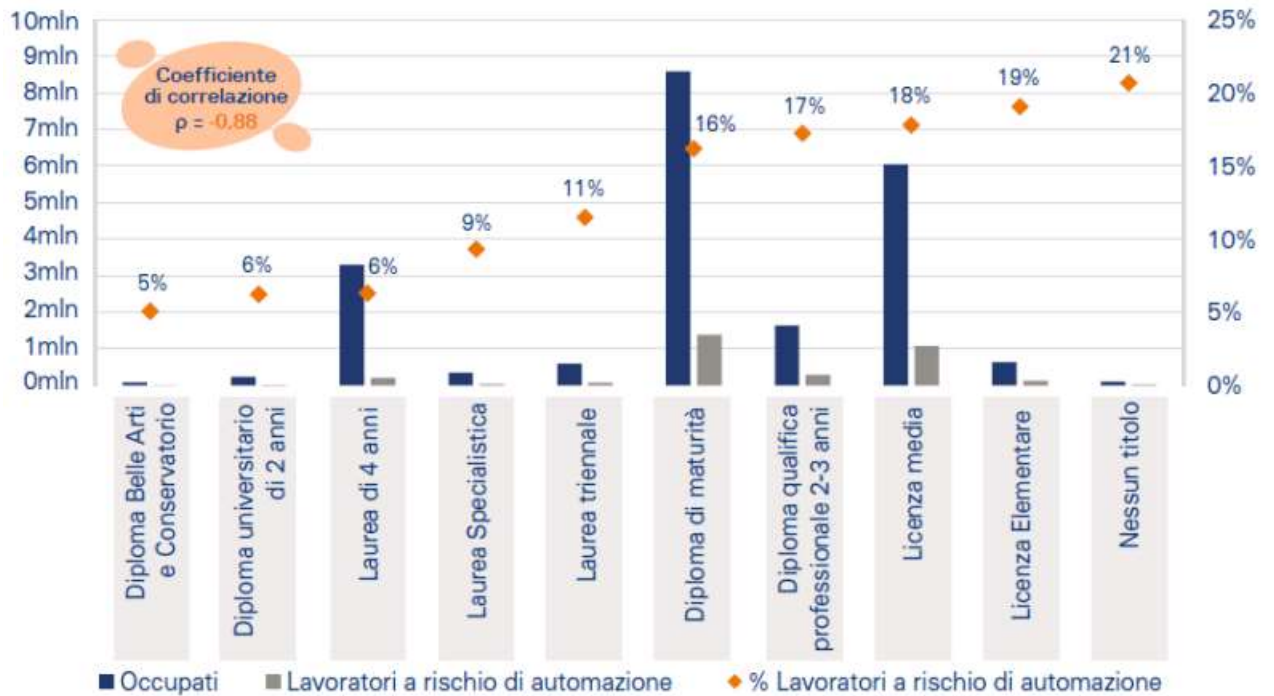
This graph illustrates the distribution of workers across different sectors in Italy, highlighting the number of workers employed, the number of workers at risk of automation, and the percentage of workers at risk of Robotics taken by 2022 data.

Low Automation Risk Sectors: Despite having a large labour force, industries like education and health care have a low automation risk, which means that jobs in these fields are not as likely to be automated.

High Automation Risk Sectors: Industries with a larger percentage of people at risk of automation include manufacturing, agriculture, and commerce. This suggests that jobs in these industries are more likely to be automated in the near future.

The multiple levels of automation risk shown in this graph can help with labour planning, legislative decisions, and economic analysis (Grimaldi, 2022).

Figure 16 - Workers at risk of automation and employed by qualification 2019



Sources: Inapp 2019

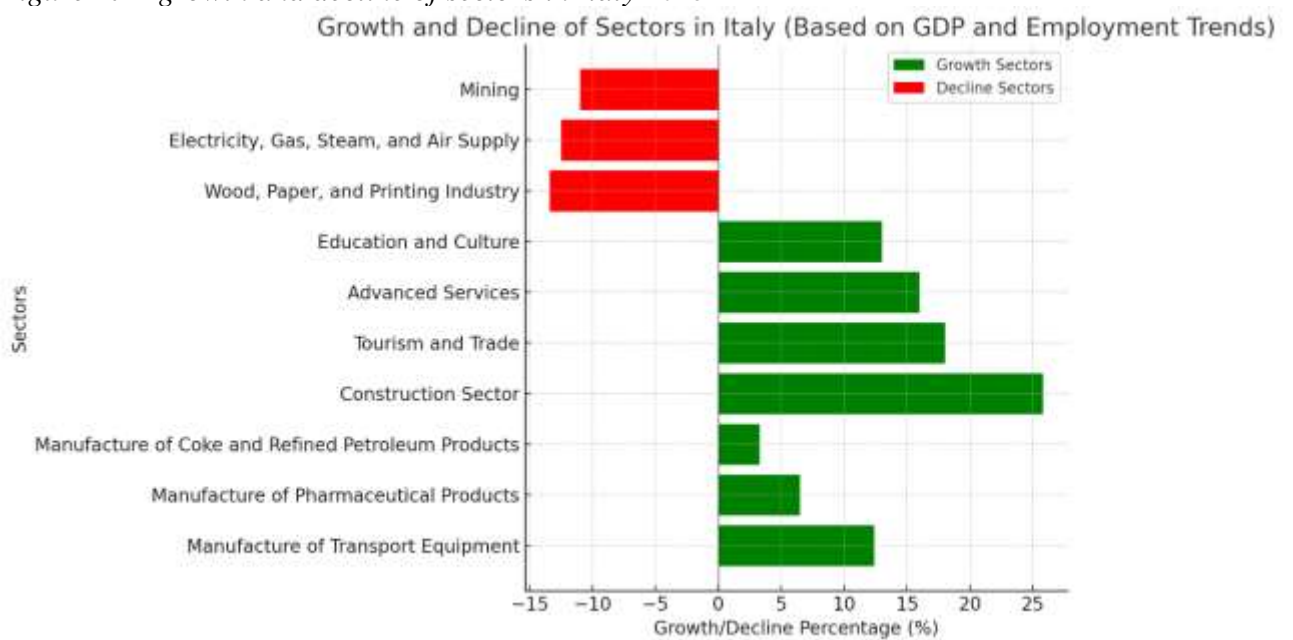
This figure provides an analysis of the correlation between educational qualifications and the risk of automation among workers in Italy. It shows how different levels of education influence both the total number of employed individuals and the percentage of those whose jobs are at risk of being automated (Saverio Lovergine, 2019)

- Higher Education and Lower Automation Risk:** The graph clearly shows that workers with higher educational qualifications (such as university degrees) are less likely to be replaced by automation. This is underscored by the strong negative correlation of -0.88.

- **Lower Education and Higher Automation Risk:** Conversely, those with lower educational qualifications or no formal education are more susceptible to job automation, as reflected by the higher percentages of at-risk workers.

This graph serves as an important indicator for policymakers and educators, suggesting that increasing educational attainment could be a key strategy in reducing the impact of automation on the workforce (Andreas Damelang, 2023).

Figure 17 – growth and decline of sectors in Italy 2023



Sources: EURES (EUROpean Employment Services 2023)

The graph provides a clear picture of the nation's changing economic environment by indicating which industries are prospering with the implementation of technologies and which are not. Through an analysis of GDP and employment changes as percentages, the graph offers important insights into the factors influencing these patterns. Industries such as the Manufacture of Transport Equipment are leading the way in terms of growth.

This notable expansion points to a robust market for items related to transportation, which may be driven by advances in technology and a heightened emphasis on

environmentally friendly mobility options. Comparably, the production of pharmaceutical products is expanding rapidly, which is not surprising considering the rise in healthcare demands around the world, especially in the wake of the COVID-19 epidemic.

Another sector that is has the most growth is the construction industry. This might be a sign of increased real estate and infrastructure investment and the utilization of robotics to perform heavy task in a better and faster way, perhaps encouraged by government programs meant to boost the economy. Meanwhile, as Italy's economy grows increasingly knowledge-based, Advanced Services which include industries like IT, banking, and other professional services—are growing. This change is indicative of a larger trend towards industries that may use technology breakthroughs to spur innovation and productivity.

It's interesting to note that the tourism and trade sectors are expanding as well, which is noteworthy considering Italy's historical dependence on these fields. This expansion may indicate a rebound from the pandemic's effects or a response to novel market circumstances, including digital travel services or environmentally friendly business methods that are starting to be digitalized with IA.

On the decline side, the graph highlights sectors like Mining and Electricity, Gas, Steam, and Air Supply. The decline in mining could be attributed to several factors, including reduced demand for traditional fossil fuels and a societal shift towards renewable energy sources. The decline in traditional utilities might also reflect the broader energy transition, as efficiency gains and the adoption of alternative energy sources reduce the demand for traditional power generation.

Another industry seeing loss is the wood, paper, and printing sector, which is probably being affected by the growing digital transition. The need for tangible paper goods is declining as more companies and customers turn to digital platforms, which has a knock-on effect on the industry's economic activities.

In order to manage these changes, it emphasizes the significance of strategic planning at the policy level as well as inside specific businesses and regulation on workers and technologies. Retraining and upskilling workers for maintaining and advance on technology. These programs are desperately needed in industries that are losing ground in order to support employees in moving to more stable jobs. Maintaining this momentum while making sure that technological improvements enhance human labour rather than replace it is the problem facing expanding industries.

The graph ultimately acts as a potent reminder of Italy's continuous economic development. In order to guarantee a fair and inclusive economic future, it draws attention to the industries that are both growing and adapting to change, as well as those that run the risk of falling behind (EURES, 2023).

CHAPTER 5. Incentives to maintain workers in companies rather than replacing them

The debate about incentives to keep employees in companies rather than replacing them with technology is relevant and crucial given the fast rise in automation and technological innovation in the last decade. Worker substitutability, as highlighted in labor economics, refers to the ease with which one worker can be replaced by another or by a technological alternative without significantly affecting productivity. As automation progresses, it becomes essential to analyze why firms may still prefer to retain human labor despite the growing potential for technological replacement.

One of the strongest incentives for firms to retain workers lies in the inherent flexibility and problem-solving capabilities of human labor. Automating jobs that demand sophisticated cognitive abilities, emotional intelligence, and individualised customer service is frequently impractical. Humans do better than technology in jobs requiring creativity, critical thinking, and social connection, but robots are better at “boring”, repetitive work. (Thiago Augusto Aniceski, 2024) This article highlights, that some jobs are more susceptible to automation than others, but jobs requiring specialized human abilities will always be more resilient as analyzed previously. Employers who retain their workforces are better prepared to respond to unforeseen circumstances and the unique demands of their clients—an area in which technology is currently lagging. Because human oversight is valuable in positions involving moral judgement and complex decision-making, also human labor is more liable to work in crisis or never seen before situations (Covid), where technologies should rely on previous data to work in an efficient way. Therefore, companies that place a higher value on human capital than on replacing technology are more likely to maintain their competitive advantages in fields that need flexibility and interpersonal interaction, but lack in field that require

levels of automation, precision, and efficiency, where technology-driven solutions are more effective than human labor optimizing processes and reducing errors.

A second reason to maintain human workers is the preservation of organizational knowledge and continuity. While machines can replicate tasks, they cannot yet capture the institutional memory and tacit knowledge that long-serving employees accumulate over time. Employees gain a profound awareness of business procedures, relationships with customers, and market dynamics—all of which are critical for strategic thinking and creative problem-solving. It is challenging to transfer this kind of knowledge capital to automated systems, which would necessitate large programming and retraining expenditures in order to accomplish jobs with a comparable degree of contextual comprehension (Duru & Özbaşaran, 2024). Moreover, when technology replaces workers, businesses run the danger of losing social capital. Collaboration, mentoring, and team dynamics are fostered by human labour and are essential to sustaining a positive organisational culture. Industries with strong unionisation rates frequently defend worker rights and support measures like retraining programs to enable employees migrate inside the company rather than face replacement, as the worker substitutability issue demonstrates.

Another major incentive is the limitation of current technology itself. Despite rapid advancements in automation, technology still has inherent boundaries. Perfect substitutability of workers is rare, as acknowledged in the text, due to the complexity of modern production processes. This emphasises the fact that technology can only supplement employees—rather than replace them—in some industries, like seen in the healthcare and hospitality. As a result, businesses retain employees not simply for operational reasons but also to strike a strategic balance between technology and human

involvement. Businesses also must consider the cost of implementing some technology that the more modern and newer they are, the higher the cost will be. Advanced automation technology can be expensive to implement initially, and the ongoing need for maintenance, updates, and troubleshooting can strain resources. Firms may find it more cost-effective to retain experienced workers who can perform tasks without the need for constant technological supervision, especially in industries where human error is less costly than machine malfunction (Liat Haber, 2023), but if a firm retrain a worker who then leaves the company, it risks losing its investment. While human error is more frequent than technological failures, the latter tend to be more serious and costly when it occurs.

Maintaining workers also aligns with broader corporate social responsibility (CSR) goals. In an era where ethical business practices and sustainable employment are increasingly valued by consumers, companies are incentivized to preserve jobs and avoid contributing to unemployment and economic inequality. Given that low-paying, highly substitutable jobs are frequently disproportionately impacted by automation, companies that value human labor may improve their standing in the community by demonstrating their dedication to social and economic stability (Etikan, 2024). Moreover, firms that avoid excessive automation and support worker retention are better positioned to mitigate economic inequality, a key concern raised by the growing automation potential.

Moreover, firms that avoid excessive automation and support worker retention are better positioned to mitigate economic inequality, a key concern raised by the growing automation potential. The negative effects of technological displacement on low-skilled

workers have been well-documented, as illustrated by Italy's case, where significant automation risks persist. Businesses that implement upskilling and retraining plans for their employees are likely to improve their economic impact and corporate image as well as show that they are committed to inclusive growth, also are viewed more favorably than companies who choose to replace workers with technology, which often draws negative attention from customers and community.

5.1 Italy's Approach to workforce Retention and Upskilling

The retention of workers is crucial for preserving the specialized skills that define Italy's key industries. Human expertise in luxury manufacturing, fashion, and automotive sectors plays a fundamental role in the quality and uniqueness of Italian products on a global scale. While automation can boost productivity, it cannot replace the intricate craftsmanship and advanced knowledge required in these fields. As a result, Italian businesses emphasize reskilling and upskilling initiatives, allowing their workforce to adopt cutting-edge technology without losing the distinctive quality of their products.

Italy's legislative framework supports worker retention through a variety of policies and programs. The national report on the implementation of the Upskilling Pathways Recommendation (Vitali, 2022), indicates a gradual increase in adult participation in education and skill development. Key stakeholders agree on a holistic approach to reskilling the workforce, and (Italy: National strategic plan for upskilling and reskilling adults, 2021-2023) plays a pivotal role in this effort.

- **Qualifying and Upskilling Human Capital:** This effort places a strong focus on personalised learning, which is especially crucial for low-skilled people who could face distinct difficulties and demands. Through customised education and training initiatives, the government can guarantee that workers receive the best possible assistance. The emphasis on socio-work inclusion also acknowledges the significance of removing social and economic obstacles that can prevent people from engaging in upskilling and reskilling initiatives (Leon, 2023).

- Intercepting and Guiding Individuals: Ensuring low-skilled individuals have access to pertinent resources and assistance is a major problem in upskilling and reskilling them. One of the most important steps in resolving this issue is the initiative taken by the Italian government to increase access to these services, providing online and evening courses. The government wants to make it simpler for people to choose appropriate training programs and negotiate the challenges of the job market by funding advice services and improving the abilities of experts in this area.

- Synchronizing Skills Supply and Demand: A well-functioning labor market requires a close alignment between the skills of workers and the needs of employers. The Italian government's initiative to improve the quality of services that match skills with labor market needs is essential for ensuring that upskilling and reskilling programs are effective. By promoting alliances between formal and informal learning, the government is also recognizing the value of a diverse range of learning experiences. (Begum & Momen, 2019).

Culturally, Italy values labor and social solidarity, providing strong incentives for companies to retain workers. Medium-sized and small enterprises (SMEs), especially family-run businesses, frequently place a high priority on their social duty to keep jobs in their communities. Strong linkages to the community and labour unions, which support worker retention and ongoing skill development, underscore this worker-first approach to automation and technology integration.

This cooperative strategy between labour unions and companies supports initiatives that emphasize skill development and lifetime learning (Kansara, 2019).

Automation's potential to increase economic inequality is a big worry for low-skilled industries like manufacturing and agriculture. By emphasising reskilling and upskilling, Italian businesses reduce this danger and aid in bridging any potential societal division brought about by greater automation. Through the government's adult learning programs, low-skilled individuals will be able to advance into more stable, skilled positions by providing disadvantaged populations with access to lifelong learning.

Italy supports human capital upskilling so that advancements in technology do not create a greater divide between skilled and unskilled workers and this will not lead to the substitution of workers with technology in all of those works where it is possible to do it. Workers who participate in customised education and training programs are better able to adjust to the shifting needs of the labour market and maintain their competitiveness, this will lead also to lowering cost for firms.

Italy has implemented various programs to incentivize worker retention. Beyond the Upskilling Pathways Recommendation and National Strategic Plan, the “Cassa Integrazione Guadagni” (CIG) program allows companies to temporarily reduce labor costs during economic downturns or restructuring without laying off workers. This program provides wage supplementation, enabling businesses to retain their workforce even in times of economic instability (OECD, 2019). These initiatives provide a morally sound substitute for layoffs, fostering job security and reducing the adverse consequences of financial difficulties. Initiatives aimed at retraining and qualifying human resources also contribute to the workforce's continued ability to adjust to new technology. Upskilling and reskilling programs keep workers relevant, allowing them to

collaborate effectively with new technologies. This enhances productivity and fosters innovation, contributing to the long-term success of Italian businesses.

CONCLUSION

Automation has been a transformative force across industries and economies, continuously reshaping labor markets and the substitutability of human workers. As technology advances at an accelerating pace, it becomes increasingly critical for businesses, policymakers, and society to understand the implications of automation on employment. Jobs characterized by routine and repetitive tasks are especially vulnerable, while roles requiring creativity, critical thinking, and interpersonal skills tend to be more resilient to be substitute respect those activities that requires know-how and adaptability.

Italy provides an interesting case study in managing the balance between technological progress and the preservation of human capital, because is having in the last few years an exponential growth in both Artificial Intelligence and Robotics, remembering that Italian firm are characterized by medium size and family businesses. Through initiatives put into act by public and private bodies but also by communities trying to align workforce skills with market needs, Italy illustrates a strategic approach to minimizing worker displacement while fostering economic growth. Other nations facing similar technological shifts could benefit from adopting comparable measures, emphasizing reskilling, upskilling, and supportive government policies to maintain labor force stability.

Looking ahead, it is vital to manage the integration of automation with human expertise thoughtfully. While automation promises significant productivity and efficiency gains, an over-reliance on machines could exacerbate job displacement and widen economic inequality. Therefore, prioritizing education, reskilling programs, and forward-looking policies will be essential to ensuring that technological advancements complement

rather than replace human labor. This balanced approach preserves the unique value of human contributions while fostering sustainable economic growth.

The future of work will be defined by the evolving relationship between automation and human labor. By acknowledging the complexities of worker displacement and adopting proactive strategies, countries can harness the benefits of technological innovation while minimizing its disruptive impact on the workforce. Italy's experience serves as a valuable example for those country that are in terms of technology use currently hang back Italy's situation, but in the coming years, they will likely catch up. By considering Italy's approach and building upon it, they can enhance their progress and achieve even greater momentum, highlighting the need for policies that promote both technological progress and social equity. As technological rapidly advances and continue to challenge traditional labor markets, it will be crucial for governments, businesses, and individuals to keep working together true time to maintain a harmonious coexistence between human labor and automation. Ensuring this balance will be key to securing a prosperous future for current and future generations.

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