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Knowledge Workers across the Italian Regions

Abstract

In the following article I take into consideration the role of knowledge workers in the Italian regions. The analysed data refers to the ISTAT-BES database. The metric analysis consists of an in-depth analysis of the trends of the regions and macro-regions, followed by clustering with the k-Means algorithm, the application of machine learning algorithms for prediction, and the presentation of an econometric model with panel methods date. The results are also critically discussed in light of the North-South divide and the economic policy implications.

JEL CODE: O3, O31, O32, O33, O34

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1) Introduction

The symbiotic relationship between knowledge workers and cultural and creative employment across Italian regions embodies a critical dynamic in understanding regional economic development and cultural vitality. Knowledge workers—individuals whose primary job involves processing information and creating knowledge—serve as the lifeblood of innovation within the creative sectors. These sectors, encompassing fields from art and design to digital media, not only contribute significantly to Italy's GDP but also to its international cultural prestige. The argument posits that the infusion of knowledge workers into the cultural and creative industries catalyzes innovation, leading to a richer cultural landscape and enhanced economic performance across Italian regions. Firstly, knowledge workers bring specialized skills, innovative methodologies, and a penchant for creative problem-solving that directly contribute to the dynamism and competitiveness of the cultural and creative sectors. Their involvement in these industries leads to the development of new products, services, and artistic expressions, thereby expanding the economic and cultural reach of these sectors. Regions such as Lombardy, Tuscany, and Veneto, which have invested in education and technology, showcase how knowledge workers can spur growth in cultural and creative employment, leading to higher levels of regional economic output and cultural richness. Secondly, the presence of knowledge workers in a region attracts further talent and investment, creating a virtuous cycle of growth and innovation. This cycle not only enhances the quality and diversity of cultural outputs but also solidifies the region's reputation as a hub for creativity and innovation. Such environments attract more knowledge workers, leading to a compounding effect on both the economy and the cultural sector. Moreover, the relationship between knowledge workers and cultural and creative employment facilitates a unique exchange of ideas and skills that enriches both the workforce and the cultural

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products they create. This exchange fosters an environment where creative endeavors are not only appreciated and supported but are also seen as integral to the region's economic and social fabric. In conclusion, the positive relationship between knowledge workers and cultural and creative employment across Italian regions illustrates a model of sustainable economic and cultural development. This dynamic interplay not only enhances the vibrancy and resilience of Italy's cultural and creative sectors but also serves as a blueprint for other regions aiming to harmonize economic development with cultural enrichment.

The article continues as follows: the second section takes into consideration the analysis of the literature, the third section presents an analysis of trends in the Italian regions and macro-regions, the fourth section presents a clustering, the fifth section the prediction through the comparison with machine learning algorithms, the sixth section presents the econometric model, the seventh section the policy implications, the eighth section concludes.

2) Literature Review

Harkiolakis & Komodromos (2023) underscore the importance of supporting knowledge workers' health and well-being in the post-lockdown era. The COVID-19 pandemic has fundamentally altered work environments, emphasizing the need for organizations to adopt more flexible work arrangements and provide support systems that prioritize mental and physical health. This research suggests that adaptive strategies are essential for maintaining productivity and well-being among knowledge workers in increasingly remote or hybrid work settings. Nazeer et al. (2023) explore the role of ChatGPT in addressing personal knowledge management challenges, highlighting the tool's potential to support knowledge workers across various disciplines. The integration of AI and machine learning technologies like ChatGPT can streamline information retrieval, enhance learning, and foster innovation. However, this also raises questions about the balance between technological reliance and human judgment, suggesting that while ChatGPT presents significant opportunities, it also requires careful implementation to complement human expertise effectively. Fujita et al. (2023) delve into the relationship between knowledge workers and their workspaces, emphasizing the importance of human-workspace interaction in supporting productivity and creativity. As work environments become more digitized, designing workspaces that cater to the needs of knowledge workers is crucial. This includes ergonomic considerations, technological integration, and spatial arrangements that promote focus and collaboration, indicating a need for ongoing research to optimize workspace design for knowledge work. Pratiwi, Hinduan, & Lubis (2024) examine the factors contributing to turnover intentions among knowledge workers, highlighting the complexity of retaining talent in competitive job markets. Factors such as job satisfaction, work-life balance, and organizational culture play significant roles in influencing knowledge workers' decisions to stay with or leave an organization. This study suggests that understanding these dynamics is critical for developing strategies to manage turnover and maintain a skilled workforce. Lastly, Khan & Nasim (2024) focus on the subjective well-being of knowledge workers, employing bibliometrics to map out research in this area. The study underscores the importance of well-being in the workplace, noting that factors such as autonomy, recognition, and personal growth significantly impact knowledge workers' job satisfaction and overall happiness. This research points to a growing acknowledgment of the need to address not only the technical skills and productivity of knowledge workers but also their emotional and psychological well-being. Integrating the insights from the provided references, we can construct a comprehensive argument regarding the evolving nature of knowledge work and its implications for well-being, professional learning, and the development of effective knowledge management practices, particularly in the context of virtual collaboration.

Tarvainen (2023) emphasizes the significance of cognitive ergonomics in enhancing the work well-being of knowledge workers. This highlights an essential aspect of workplace design that goes beyond physical ergonomics to include the mental and cognitive aspects of work. Cognitive ergonomics focuses on aligning work processes, tools, and environments with the way people think, learn, and process information. By optimizing for cognitive ergonomics, organizations can reduce mental fatigue, improve concentration, and enhance overall job satisfaction among knowledge workers, thereby fostering a more productive and healthy work environment. Segura-Rodas et al. (2023) delve into the specific knowledge work activities involved in conducting systematic reviews, providing insight into the complexities and challenges of this type of work. This research points to the need for tools and methodologies that can support the intricate processes of data collection, analysis, and synthesis. Understanding these activities can inform the development of more efficient and user-friendly information systems, which in turn can enhance the productivity and effectiveness of knowledge workers engaged in research and evidence synthesis. Ventista and Brown (2023) explore the relationship between teachers' professional learning and its impact on students' learning outcomes. This study underscores the importance of continuous professional development for educators, not just as a means of personal growth, but as a critical factor influencing student success. The findings suggest that investing in teachers' learning and development can have a direct and positive effect on educational outcomes, highlighting the interconnectedness of knowledge work in the educational sector. Yan, Geng, & Gao (2023) address the concept of decent work for knowledge workers by constructing and validating a new scale to measure this construct. Their research acknowledges the evolving needs and expectations of knowledge workers regarding job quality, work-life balance, and workplace well-being. By focusing on the criteria for decent work, organizations can better assess and improve the working conditions of knowledge workers, ensuring that they are supported in ways that respect their needs and contributions. Pedersen et al. (2023) examine the capabilities required for effective knowledge management in the context of virtual collaboration. As remote and virtual work arrangements become more prevalent, understanding how knowledge can be shared, stored, and applied across distributed teams is crucial. This study highlights the need for systematic approaches and tools that facilitate seamless knowledge exchange in virtual settings, ensuring that teams can collaborate effectively despite geographical separation.

Erdiauw-Kwasie et al. (2023) highlights the vulnerability of Small and Medium Enterprises (SMEs) to pandemic risks and explores their coping strategies and resilience. The importance of this study lies in its comprehensive analysis of the multifaceted challenges SMEs face during crises and the innovative approaches they adopt to survive. It underscores the necessity for supportive policies and frameworks that enhance SME resilience, contributing significantly to literature on crisis management and business continuity planning. Gorbatov et al. (2024) examines the role of personal branding in the employability of knowledge workers, this study adds a unique perspective to the employment literature. It challenges the conventional wisdom that work quality alone determines employability by demonstrating the incremental validity of personal branding. This insight is crucial for knowledge workers and HR professionals alike, as it emphasizes the importance of personal branding strategies in career development and talent management. Rogozińska-Pawelczyk (2023) focuses on the positive impact of inclusive leadership on psychological contract fulfillment, proactivity, and well-being among knowledge workers. It contributes to the leadership and organizational behavior literature by highlighting the role of inclusive leadership practices in fostering a supportive and fulfilling work environment. This is particularly relevant in a world where workplace diversity and inclusion are increasingly recognized as key drivers of innovation and organizational success. Wang & Yu (2023) investigates the influence of spousal support on the outcomes and willingness to work from home among female knowledge workers, this study addresses

a gap in the ergonomics and work-life balance literature. It reveals the critical role of spousal support in enabling effective work from home arrangements, offering valuable insights for organizations and policymakers aiming to promote gender equality and support work-life integration in the evolving work landscape. Ghorbanali et al. (2023) presents a model for attracting and retaining knowledge workers in Iran's aviation industry, this study contributes to the strategic HRM and policy development literature. It underscores the importance of evidence-based policy-making in addressing sector-specific challenges and enhancing organizational competitiveness. By focusing on the aviation industry, it provides sector-specific insights that can inform policy development and talent management strategies in similar contexts.

Muzam, J. (2023) discusses the impact of the modern economy on the competencies required by knowledge workers. It likely examines the changing skills and attributes needed to navigate the complexities of contemporary work environments within the knowledge economy. Alyusuf, A. (2023) focuses on the transition from the traditional notion that merely possessing knowledge is power to the idea that voluntarily sharing knowledge is more powerful. This piece likely explores how personality traits and motivation for sustainability influence this shift, especially in the context of AI and business innovation. Vogl, T., Sinityna, A., & Micek, G. (2024) conducts a systematic literature review on the factors influencing the location of coworking spaces in non-urban areas, contributing to our understanding of the changing nature and geography of workspaces in the context of new working practices. Baltuttis, D., Teubner, T., & Adam, M. T. (2024) develops a typology of cybersecurity behaviors among knowledge workers, addressing an essential aspect of the modern workplace. This research is crucial for understanding how knowledge workers interact with cybersecurity measures and protocols. Hwang, Y., Lin, H., & Shin, D. (2023) examines the roles of information formality motivation, social influence, and goal commitment among knowledge workers. This empirical study likely sheds light on the factors that drive knowledge workers' engagement and productivity.

Nugapitiya, O., & Wickramarachchi, R. (2023) presents strategies to manage information overload in the workplace through a systematic literature review. The focus is on identifying effective practices that can mitigate the overwhelming influx of information that employees face. A critical question might be how these strategies are adaptable to different organizational cultures and the extent to which technology is leveraged to facilitate these strategies. Khatri, P., et al. (2023) explores the relationship between leadership styles that are knowledge-oriented and the agility of work processes in a hybrid setting. It suggests that heterogenous knowledge-oriented leadership enhances knowledge acquisition and hybrid work agility among knowledge workers. One could argue about the scalability of such leadership styles across different sectors and the measures used to quantify agility and knowledge acquisition. Herlina, M. G., & Syahchari, D. H. (2023) investigates intergenerational ambidextrous behavior among knowledge workers, focusing on the ability to simultaneously exploit existing competencies while exploring new opportunities. A point of contention might be the generalizability of the findings given the model's specific mathematical and statistical assumptions and whether it fully captures the nuanced behaviors of different generations in the workplace. Chow, K., et al. (2023) evaluates a digital intervention inspired by therapeutic practices aimed at reducing stress and enhancing productivity among knowledge workers. The critical evaluation could focus on the intervention's long-term efficacy, user engagement levels, and its adaptability to various work environments. Furthermore, the role of user privacy and data security in the deployment of such interventions could be examined. Sari, E. R., & Junedi, S. S. (2023) assesses the application of knowledge management in research and development institutions, highlighting the benefits and challenges faced. Critical viewpoints might include the diversity of knowledge management practices

across different R&D environments and how institutional culture influences the adoption and effectiveness of these practices.

Gerlitz, A., & Hülsbeck, M. (2023) delves into how new office concepts, such as open-plan offices, activity-based working, and single-office setups, affect productivity. The notion of a "productivity tax" suggests that while these concepts aim to foster collaboration and flexibility, they may have unintended negative impacts on worker productivity. This is a critical area of research given the widespread adoption of innovative office designs in modern workplaces. The comparative review offers insights into how organizations can balance the benefits of these designs against their potential downsides. Ayinde, L., Wibowo, M. P., Ravuri, B., & Emdad, F. B. (2023) recognizes ChatGPT as a transformative tool in organizational management, offering a comprehensive review of its applications and implications. It underscores the potential of AI and language models to streamline operations, facilitate decision-making, and enhance communication within organizations. The findings contribute to the understanding of how AI tools like ChatGPT can be leveraged to improve efficiency and effectiveness in managerial contexts. Yen, Y. Y., Zhang, C. Y., & Yen, W. T. M. (2024) is pivotal for organizations undergoing digital transformation. Knowledge workers are crucial in driving innovation and maintaining competitive advantage in digitally evolving markets. The research highlights strategies to retain such valuable human resources, emphasizing the importance of creating an engaging and supportive work environment that encourages continuous learning and development. Ren, Y., & Clement, J. (2024) explores the integration of robots into human teams within knowledge work settings. It provides valuable insights into how robotic augmentation can enhance team performance, support human workers, and potentially transform workplace dynamics. The findings from the literature review offer a nuanced understanding of the opportunities and challenges presented by human-robot collaboration, contributing to the ongoing discourse on the future of work. Shah, S. T. H., Shah, S. M. A., & El-Gohary, H. (2023) addresses the critical role of workplace learning in fostering innovative work behavior among employees of small and medium-sized enterprises (SMEs). Innovation is a key driver of growth and competitiveness, especially for SMEs. By highlighting the link between workplace learning and innovation, the study provides practical implications for how SMEs can cultivate a culture of continuous improvement and creativity among their knowledge workers.

Satarova et al. (2023), inquiries pertain to how the review accommodates the evolving definition of "knowledge organizations" and the selection criteria for included studies, raising questions about the temporal applicability of their findings. Hussain et al. (2024) prompt a critical evaluation of their narrative review's objectivity amidst inherent political biases and the frameworks proposed for curricula to reflect ongoing political realities. Jayaram and Bhatta (2023) introduce a conceptual model for tacit knowledge management, leading to questions about the model's methodological robustness and its versatility across different engineering industries. Chen et al. (2023) investigate the impact of tourism recovery experiences on creativity, which begs a deeper understanding of how these experiences are quantified and the role of travel companions. Lastly, Woodruff et al. (2023) explore perceptions of generative AI's impact, necessitating a critical look at how these perceptions are measured and their variance across industries.

3) Rankings and trends of the Italian regions and macro-regions

The percentages vary significantly between regions, from a minimum of 14% in Valle d'Aosta to a maximum of 23.2% in Lazio. Lazio (23.2%), Molise (18.9%), and Campania (19.2%) have the highest percentages of knowledge workers. This may reflect a greater concentration of knowledge-based industries and services, such as IT, financial services, education and research. Valle d'Aosta (14%), Trentino-Alto Adige (14.8%), and Veneto (15.6%) show the lowest percentages. These regions may have economies more oriented towards agriculture, tourism or manufacturing, rather than knowledge-intensive sectors. There is some variability between the regions of northern and southern Italy, with some southern regions such as Molise and Campania outperforming several northern regions. This could challenge the common idea of a North-South divide in terms of advanced economic sectors. Regions with the highest percentages of knowledge workers tend to have large urban centers or regional/national capitals (e.g. Rome in Lazio), which attract knowledge-based industries. The variability between regions highlights the diversity of regional economies in Italy, with some more oriented towards industry and others towards services. Regions with lower percentages of knowledge workers may have growth potential in knowledge-based sectors, leveraging policies to incentivize higher education, research and development, and technological innovation (Figure 1).

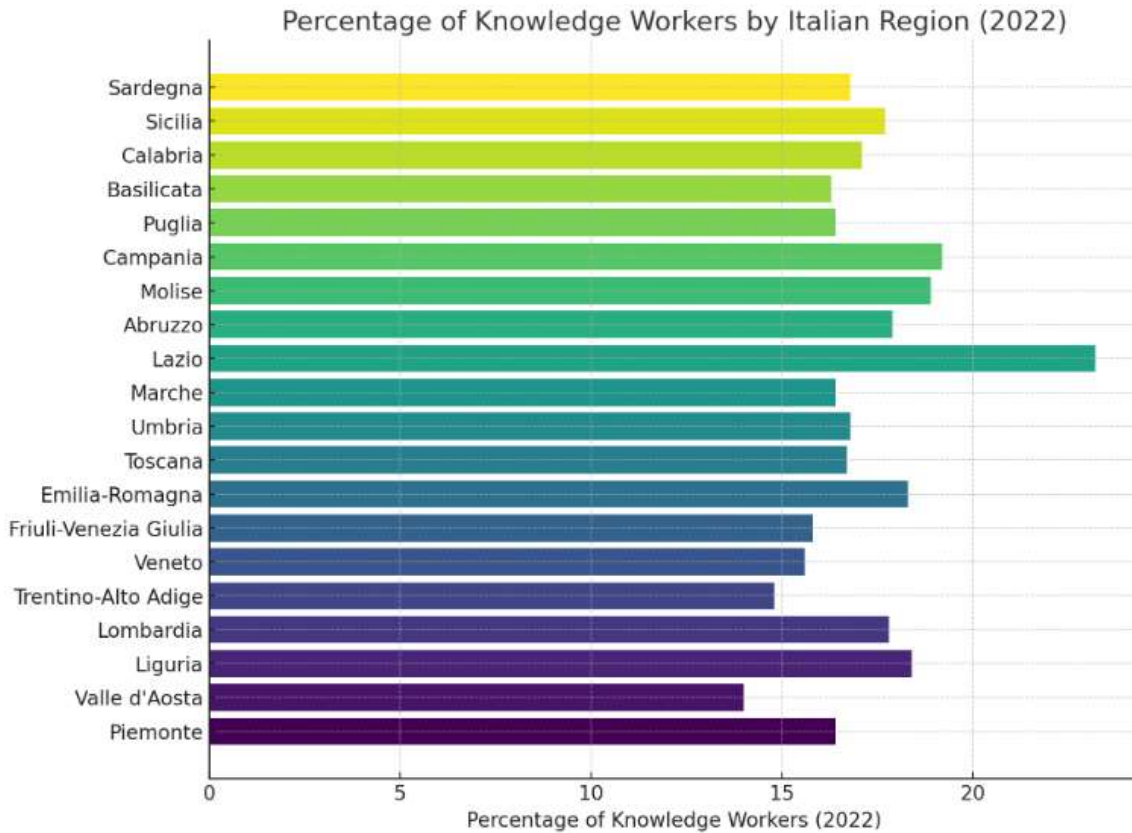


Figure 1. Knowledge workers across Italian regions. ISTAT-BES data. Author's elaboration.

The notable growth in the percentage of knowledge workers in traditionally less developed regions, such as Calabria, Basilicata, and Campania, indicates a significant economic transformation that could have profound impacts on the Italian economy as a whole. These changes are particularly relevant in a global context where the knowledge economy plays an increasingly central role, shifting the focus of development from traditional manufacturing and agricultural industries towards sectors such as IT, financial services, research and development, and education. Growth in these regions suggests unexplored potential which, if adequately supported by targeted policies, could not only

stimulate local economic growth but also help reduce the development gap between northern and southern Italy. On the other hand, the decrease observed in economically strong regions such as Lombardy and Liguria raises questions about the sustainability of the current development model and the need to adapt to the new realities of the global economy. This may imply the need for these regions to invest more in innovation, research and development, and higher education, to maintain their competitiveness and attractiveness for knowledge workers. Furthermore, the growing trend in the South can be seen as an opportunity for Italy to better balance its economy, exploiting the different strengths and potentials of its regions. Investment in digital infrastructure, specialized education and training, and the promotion of an innovation-friendly ecosystem can serve as catalysts to accelerate this transformation. Such an approach would not only stimulate economic growth and skilled employment in less developed regions but could also provide new opportunities to revitalize and diversify regional economies across the country. In conclusion, changes in the distribution of knowledge workers across Italian regions reflect challenges and opportunities in the broader context of the global knowledge economy. Addressing these dynamics with proactive and strategic policies could not only strengthen Italy's position in the world economy but also promote more equitable and sustainable development within the country (Figure 2).

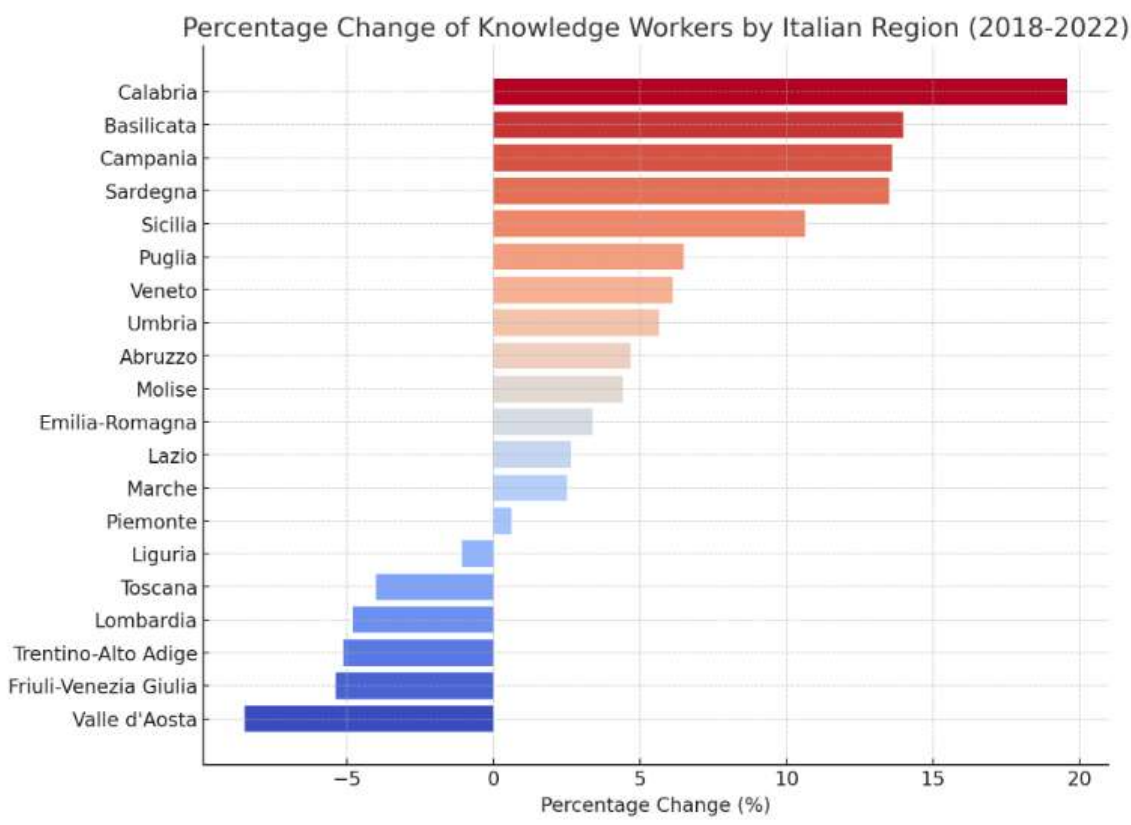


Figure 2. Percentage change in the number of knowledge workers across Italian regions from 2018 to 2022. ISTAT-BES data. Author's elaboration.

The significant growth of knowledge workers in the South, contrasted by the slight contraction observed in the regions of Northern Italy between 2018 and 2022, highlights new and unexpected regional development dynamics. This trend could be interpreted through various lenses, including changes in economic policies, technological evolution and individual worker preferences. First, state incentives and regional development policies may have played a crucial role in promoting the attractiveness of the South for knowledge-based industries. Tax incentives, investments in digital

infrastructure and support for the creation of start-ups may have created a more favorable ecosystem for innovative and technological businesses, attracting talent and promoting job growth in these areas. At the same time, digitalisation and the normalization of teleworking, accelerated by the COVID-19 pandemic, have made physical proximity to traditional work centers less relevant. This has allowed knowledge workers to choose to live in regions with a lower cost of living or a higher quality of life, as is often found in the South compared to the dense and expensive urban areas of the North. This internal "brain drain" supports not only a geographical redistribution of talent but also an economic revitalization of the southern regions. Furthermore, growth in the South could reflect a phase of technological and economic catch-up, where previously less developed regions are rapidly closing the gap with their more advanced counterparts, exploiting technology and innovation as development levers. However, it is important to note that this positive trend in the South should not obscure the need for continuous and targeted support for all regions. The decline, albeit slight, observed in the North and Northwest requires attention to avoid crystallizing into a broader negative trend, potentially exacerbated by a lack of investment or a talent drain. In conclusion, the transformation observed in the distribution patterns of knowledge workers in Italy underlines the importance of inclusive regional economic and development policies, which promote equity between regions, exploit new technologies and respond flexibly to the needs of workers in the post-pandemic landscape (Figure 3).

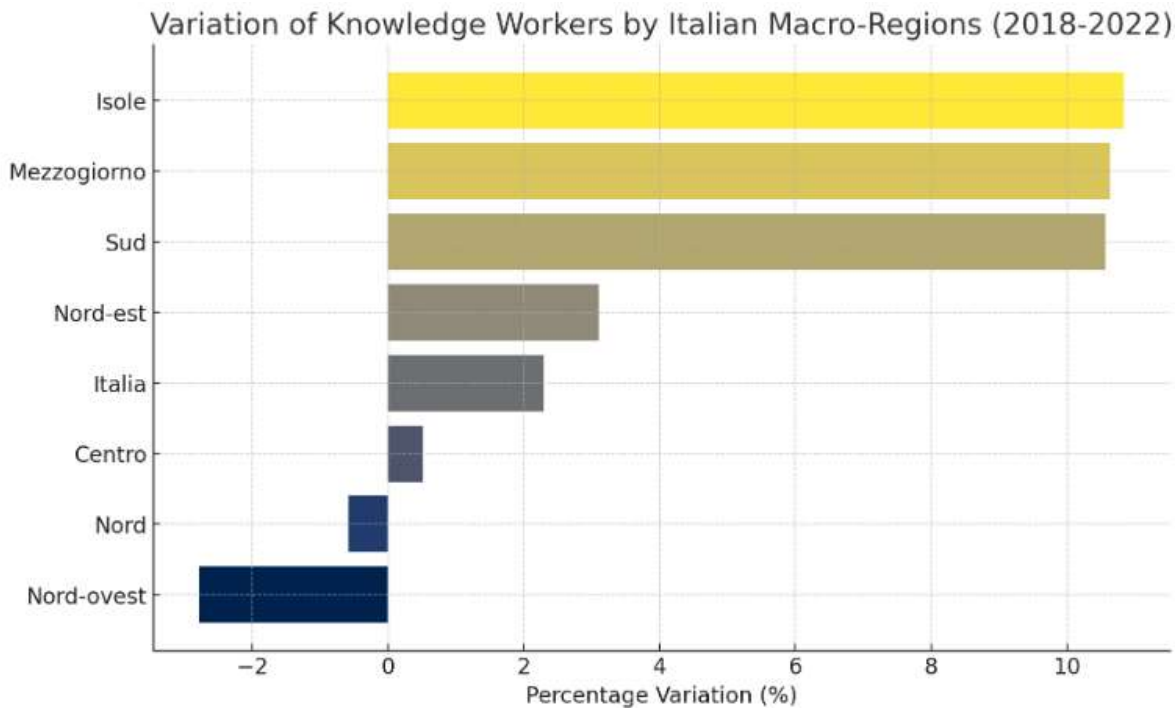


Figure 3. Percentage variation of knowledge workers across Italian macro-regions from 2018 to 2022.

Based on 2022 data, the average percentage of knowledge workers in Italian regions shows an interesting geographical pattern:

- The average for the Northern regions is 16.39%;
- The Central regions show an average of 18.28%, the highest among the three geographical areas;
- The South has an average of 17.54%;

These results indicate that, contrary to what one might assume by looking only at general economic data, the gap between North and South in terms of the percentage of knowledge workers is not as stark as one would expect. In fact, the South has a higher average than the North, although both are surpassed by the Central regions, thanks in particular to Lazio which stands out with a significantly high percentage of knowledge workers. While a gap exists between the Center and the other two areas, the South shows remarkable resilience, challenging the assumption of a clear economic and development gap with the North in terms of knowledge workers. This may suggest that the South is making significant progress in specific sectors of the knowledge economy, a positive sign for the country's prospects for growth and balanced development.

The data suggests a trend towards a narrowing gap between North and South in terms of the percentage of knowledge workers, with the South showing signs of dynamism and growth. This can be interpreted as the result of policies aimed at promoting innovation, investment in human capital and digitalisation, which are gradually transforming the economic landscape of Southern Italy. However, volatility and decline in some regions of the North and Center require continued attention to ensure that these areas remain competitive in the global knowledge economy. Addressing these challenges and supporting growth in all regions will require inclusive policies that promote advanced education, innovation and technological infrastructure, thus ensuring that Italy as a whole can thrive in the era of the knowledge-based economy .

4) Clusterization with k Means Algorithm Optimized with Silhouette Coefficient

The cluster analysis of Italian regions based on the data concerning knowledge workers from 2018 to 2022 has identified an optimal number of 2 clusters, optimized with a Silhouette Coefficient of approximately 0.687. This suggests a relatively high degree of separation between the clusters, indicating that the data points within each cluster are closer to each other than to those in other clusters. The distribution of regions across the two clusters suggests distinct patterns in the evolution of knowledge worker percentages over the considered years, potentially reflecting different economic development paths, industrial focuses, or policy impacts within these clusters of regions. The clustering analysis has grouped the Italian regions into two clusters based on the data of knowledge workers from 2018 to 2022:

- Cluster 0: includes Piemonte, Valle d'Aosta, Liguria, Lombardia, Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia, Emilia-Romagna, Toscana, Umbria, Marche, Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, Sicilia, and Sardegna.
- Cluster 1: consists solely of Lazio.

This outcome highlights Lazio's distinct pattern in the evolution of knowledge worker percentages, significantly differing from the other regions. This could reflect Lazio's unique economic, educational, or industrial characteristics, possibly driven by the concentration of national governmental, financial, and educational institutions in the region, including the capital city of Rome. This clustering is inefficient as cluster 0, i.e. the dominant cluster, is composed exclusively of the Lazio region. For this reason we analyse the value of the Silhouette coefficient for various levels of k between 3 and 8 in order to identify a suboptimal level of k yet greater than k=2. The Silhouette Coefficients for different values of k (from 3 to 8) are as follows:

- k=3: 0.4549
- k=4: 0.3215
- k=5: 0.2813

- k=6: 0.2767
- k=7: 0.3114
- k=8: 0.3000

In this case verify that k=3 represents the value of the highest Silhouette coefficient at the suboptimal level. We therefore choose k=3. With k set to 3 for the clustering analysis, the Italian regions are grouped into three clusters as follows:

- Cluster 0: includes Piemonte, Valle d'Aosta, Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia, Toscana, Umbria, Marche, Puglia, Basilicata, Calabria, Sicilia, and Sardegna.
- Cluster 1: consists of Liguria, Lombardia, Emilia-Romagna, Abruzzo, Molise, and Campania.
- Cluster 2: contains only Lazio.

This division suggests a finer differentiation between the regions, particularly distinguishing Lazio as a unique cluster due to its distinct pattern in the evolution of knowledge worker percentages. Cluster 1 appears to include regions with moderate to high percentages of knowledge workers and possibly similar economic structures or development levels, whereas Cluster 0 encompasses a mix of regions with diverse economic backgrounds (Figure 4).

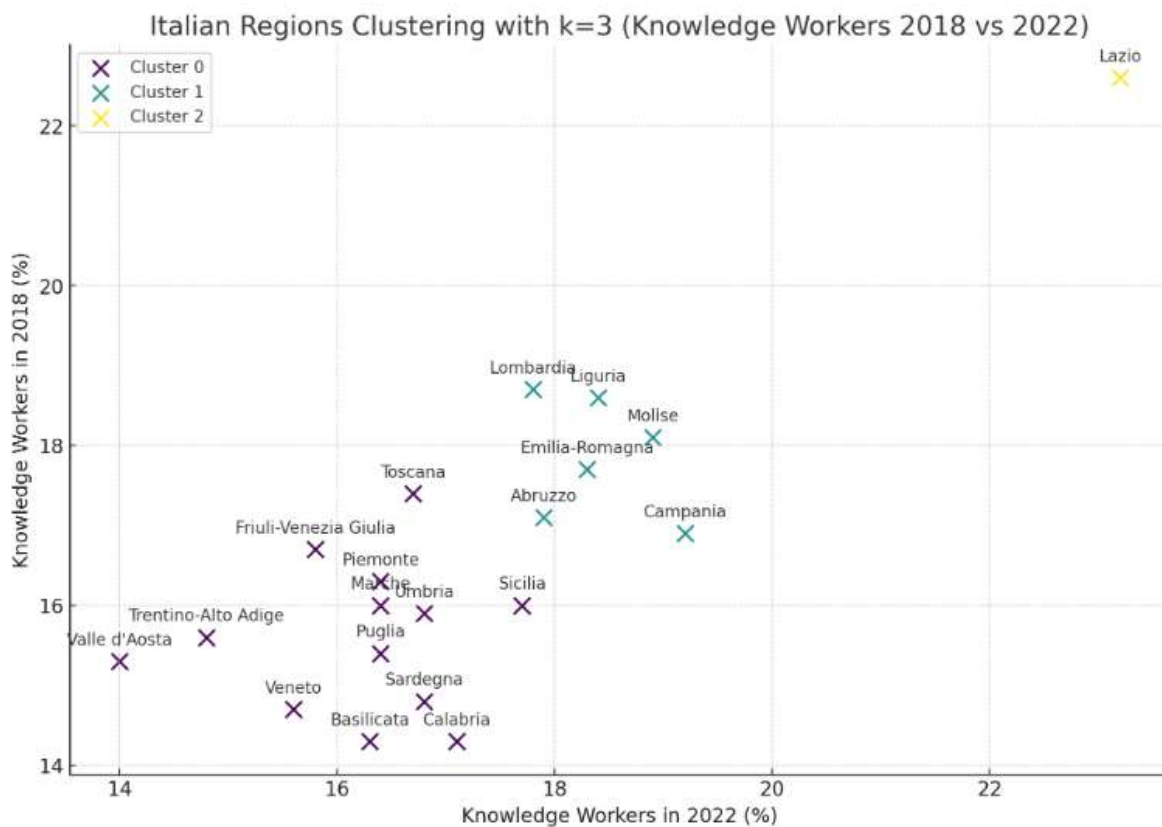


Figure 4. Clusterization with k-Means algorithm optimized with the Silhouette coefficient with k=3. Author's elaboration. Source: ISTAT-BES.

The clustering analysis of Italian regions, based on the evolution of knowledge worker percentages from 2018 to 2022, uncovers distinct regional trends. Cluster 0, comprising regions with minimal to moderate changes, suggests areas where the knowledge sector has remained relatively stable, reflecting either mature or gradually evolving knowledge economies. This stability or slight growth

in knowledge worker percentages could be influenced by broader, possibly global trends rather than significant local developments. Cluster 1, which includes regions like Lombardia and Emilia-Romagna, displays a positive trend in knowledge worker growth. This suggests a shift towards more knowledge-intensive industries, possibly in response to technological advancements and a strategic push towards a more innovation-driven economy. These regions might be leveraging their existing economic strengths and infrastructure to transition into or bolster their position within the knowledge economy. Finally, Cluster 2, uniquely occupied by Lazio, highlights the region's standout growth in knowledge workers, likely reflecting its role as a national and international center for government, education, and research activities. The distinct separation of Lazio from other regions underscores the impact of concentrated policy efforts, investment in education and technology, and the presence of key institutions that drive the demand for knowledge workers. Together, these clusters not only delineate the current landscape of knowledge workers across Italy but also hint at the varying regional dynamics and factors propelling changes within the knowledge economy. This analysis could serve as a basis for targeted policy development, aiming to bolster regions' economic resilience and growth by nurturing and attracting knowledge-intensive sectors.

5) The Econometric Model

Below we present an econometric model for estimating the determinants of KW in the Italian regions. Specifically, we used the following models: Panel Data with Fixed Effects, Panel Data with Random Effects, Pooled OLS, WLS. We estimated the following equation:

$$KW_{it} = \alpha + \beta_1(CCE)_{it} + \beta_2(RIU)_{it} + \beta_3(AOC)_{it} + \beta_4(MIG)_{it} + \beta_5(SI)_{it}$$

Where $i=20$ and $t=[2004;2022]$. The econometric results are showed in the appendix.

We found a positive relationship between KW and the following variables:

- **CCE:** the positive relationship between KW and CCE across Italian regions is grounded in the understanding that knowledge workers—individuals whose main capital is knowledge, such as software engineers, architects, engineers, scientists, and educators—play a pivotal role in the innovation and creativity sectors. This relationship is particularly evident in the context of Italy, a country renowned for its rich cultural heritage and vibrant creative industries. Knowledge workers contribute to the cultural and creative sectors by bringing innovative solutions and new technologies that enhance creativity, production, and distribution in fields such as digital media, design, and arts. The fusion of technological innovation with cultural content can lead to new forms of creative expressions and cultural goods. Regions with a high concentration of knowledge workers tend to exhibit stronger economic growth and resilience. This is because knowledge workers drive the knowledge-based economy, which is closely linked to the cultural and creative sectors. In Italian regions where both knowledge workers and cultural and creative employment are abundant, there is a symbiotic relationship that fosters economic development, attracting investments and tourism. Italy's cultural heritage is one of its most significant assets. Knowledge workers can play a crucial role in preserving, enhancing, and promoting this heritage using new technologies and innovative approaches. This not only contributes to the cultural sector but also opens up new opportunities for creative employment, from digital restoration projects to virtual reality tours. The presence of knowledge workers can lead to the development of creative clusters or hubs, which become focal points for cultural and creative industries. These hubs not only contribute to the local economy but also help in strengthening regional identity and promoting cultural diversity. Italian regions such as Tuscany, Lombardy, and Emilia-Romagna have seen the benefits of

fostering such environments where innovation and culture thrive together. Knowledge workers often contribute to the educational ecosystem through universities and research centers, which are crucial for the development of skills required in the cultural and creative sectors. This relationship ensures a continuous supply of skilled professionals who can contribute to both traditional and emerging fields within the cultural and creative industries. In a globalized world, the integration of knowledge workers into the cultural and creative sectors can enhance Italy's competitiveness on the international stage. By leveraging the country's cultural assets along with innovation and technology, Italian regions can attract global talent and audiences, further boosting the cultural and creative industries. In conclusion, the positive relationship between knowledge workers and cultural and creative employment across Italian regions is evident through the mutual benefits of innovation, economic development, cultural heritage enhancement, regional identity, education, and global competitiveness.

- RIU: the relationship between "Knowledge Workers" and "Regular Internet Users" across Italian regions illustrates a dynamic interplay that can foster economic growth, enhance social inclusion, and accelerate innovation. Knowledge workers, who rely on their intellectual capabilities and expertise in fields such as IT, finance, education, and research, significantly contribute to the digital ecosystem. Regular internet users, on the other hand, encompass a broader segment of the population engaging with digital platforms for various purposes including communication, entertainment, education, and commerce. Knowledge workers play a crucial role in advancing digital literacy among the general population. Through educational initiatives, development of user-friendly digital platforms, and public policy advocacy, they help bridge the digital divide. This is particularly important in Italian regions with varied levels of digital infrastructure and access. Increasing digital literacy among regular internet users not only fosters social inclusion but also enables individuals to participate more fully in the digital economy. The interaction between knowledge workers and regular internet users is a driving force for innovation. Knowledge workers develop technologies and digital solutions that cater to the needs of the broader public. Feedback from regular internet users, in turn, guides improvements and adaptations that make technological solutions more accessible, user-friendly, and effective. This cycle of innovation and feedback is crucial for the development of digital services and products that meet the diverse needs of society. Knowledge workers contribute to the economic vitality of Italian regions by driving the knowledge-based economy. Regular internet users, equipped with digital tools and services developed by knowledge workers, can engage in entrepreneurial activities, e-commerce, remote work, and continuous learning. This symbiosis enhances economic opportunities and contributes to the regional economic development by creating jobs, stimulating innovation, and attracting investments. The collaboration between knowledge workers and regular internet users has the potential to significantly enhance the quality of life in Italian regions. Knowledge workers develop digital health solutions, educational platforms, and smart city technologies that improve access to services, reduce inefficiencies, and promote sustainable living. Regular internet users benefit from these advancements, experiencing improved access to healthcare, education, and public services. In Italy, a country with rich cultural heritage and social diversity, the digital space offers unique opportunities for cultural expression and social engagement. Knowledge workers create digital platforms that enable regular internet users to explore cultural content, participate in social movements, and engage with communities both locally and globally. This fosters a sense of belonging and contributes to the cultural vitality of the regions. Regular internet users provide valuable feedback on digital products and

services, enabling knowledge workers to adapt and refine their offerings. This feedback loop ensures that technological advancements are aligned with user needs and preferences, leading to higher adoption rates and satisfaction among the general population. In sum, the positive relationship between knowledge workers and regular internet users across Italian regions catalyzes a virtuous cycle of innovation, economic growth, and social inclusion.

We found a negative relationship between KW and the following variables:

- AOC: the argument concerning the negative relationship between "KW" and the "AOC" across Italian regions can be approached from several nuanced perspectives. This relationship might not be directly negative in the conventional sense but can highlight disparities, challenges, and unintended consequences within the socio-economic fabric of Italian society. A high concentration of knowledge workers in certain Italian regions could exacerbate the digital divide. Knowledge workers typically have higher incomes and better access to digital technologies, including computers and internet connectivity. Their presence in specific areas might drive up the cost of living and contribute to a socio-economic environment where only certain segments of the population can afford these technologies. This disparity can lead to unequal access to information, education, and economic opportunities, further marginalizing those without adequate digital access. Regions with a significant number of knowledge workers might attract more investment in digital infrastructure, diverting resources from less economically prosperous areas. This can lead to a scenario where regions already lagging behind in terms of digital connectivity find it even harder to catch up, as investments tend to flow towards areas with a higher return on investment, which are often those with a dense population of knowledge workers. The rise of knowledge workers often correlates with an increase in remote work, which requires robust internet connections and technological setups. This demand can strain local internet infrastructure, potentially leading to bandwidth allocation issues that affect the quality of internet access for regular families. In areas not equipped to handle this surge in demand, families might experience slower internet speeds or more frequent service disruptions, impacting students, teleworkers, and others who rely on the internet for daily activities. The influx of knowledge workers into specific Italian regions can lead to gentrification, where rising rents and living costs displace long-standing communities. This process can indirectly affect the availability and affordability of digital technologies for existing residents. As the cost of living increases, lower-income families might prioritize other essentials over digital tools and connectivity, thereby widening the digital divide. Knowledge workers often possess advanced digital skills and have access to cutting-edge technologies, setting a high bar for digital literacy and competencies. This can create an educational gap where the average family without similar access feels left behind, struggling to keep up with the evolving digital landscape. Schools in areas without a significant presence of knowledge workers might not offer advanced computer science or digital literacy programs, limiting students' ability to develop necessary skills. In regions dominated by traditional industries with fewer knowledge workers, there might be a lower perceived necessity for digital access, leading to underinvestment in digital technologies at the family level. This cultural and economic context can result in a slower adoption rate of digital tools and internet connectivity, further reinforcing regional disparities in digital access. To address these issues, it is crucial for policymakers and stakeholders to implement inclusive digital policies that ensure equitable access to digital technologies and internet connectivity across all Italian regions. This includes investing in digital infrastructure in underserved areas,

providing subsidies or financial assistance for low-income families to acquire digital devices and internet access, and enhancing digital literacy programs to bridge the skills gap.

- **MIG:** the negative relationship between "KW" and the "MIG" across Italian regions can be viewed through the lens of economic geography, labour market dynamics, and regional disparities in Italy. This relationship hinges on several factors that influence the mobility patterns of graduates, potentially leading to brain drain, regional imbalances, and challenges in local development. Knowledge workers, including highly skilled professionals, tend to cluster in urban centers and regions with advanced technological infrastructure and dynamic job markets, such as Lombardy, Lazio, and Emilia-Romagna. This concentration creates attractive hubs for Italian graduates seeking employment opportunities, leading to a migration flow from rural or less developed regions to these urban areas. While this can benefit the regions receiving the influx, it can detrimentally affect the regions left behind, stripping them of their educated workforce. The disparity in economic opportunities between different Italian regions can exacerbate the mobility of graduates. Regions with a high density of knowledge workers often offer better career prospects, higher salaries, and more innovative work environments, attracting graduates from across the country. This phenomenon can lead to a talent drain in less developed areas, which struggle to retain their educated youth, further widening the gap in economic and social development. The mobility of graduates towards regions with a high concentration of knowledge workers can negatively impact the innovation capacity and development prospects of the regions they leave. The departure of highly skilled individuals reduces the potential for local innovation, entrepreneurship, and economic diversification, making it challenging for these areas to break out of cycles of underdevelopment and dependency on traditional industries. The migration of graduates can lead to a brain drain in certain Italian regions, undermining social cohesion and community resilience. As educated young people leave, the social fabric of their home regions can weaken, affecting local cultures, traditions, and support networks. This loss of human capital can have long-term detrimental effects on the vitality and sustainability of communities. The uneven distribution of knowledge workers and the consequent mobility of graduates can exacerbate inequalities in access to services and quality of life between regions. Urban and wealthier regions with a high concentration of knowledge workers and graduates may have better access to healthcare, education, and cultural activities, contributing to a cycle of inequality that disadvantages less developed areas. While the influx of graduates into regions with a high concentration of knowledge workers can stimulate economic growth, it can also put pressure on urban infrastructure, housing, and public services. This can lead to increased living costs, congestion, and environmental strain, affecting the quality of life even in economically prosperous areas. Policies aimed at regional development, investment in education and innovation in less developed areas, incentives for businesses to establish operations outside major urban centers, and improved connectivity and infrastructure can help mitigate the negative effects.
- **SI:** the negative relationship between KW and the IS across Italian regions delves into the complex dynamics between the distribution of highly skilled professionals and the focus or investment in scientific research within those areas. This relationship can manifest through several channels, leading to disparities and challenges in regional development, research opportunities, and innovation capabilities. In Italy, as in many countries, there is often an uneven distribution of resources and investments, including those allocated to scientific research. Regions with a high concentration of knowledge workers, typically urban and economically developed areas, might attract more investment in research and development

(R&D), overshadowing the needs of other regions. This concentration can lead to a negative relationship in less developed areas, where the intensity of scientific research may remain low due to the lack of financial resources, infrastructure, and human capital. The presence of knowledge workers in specific regions can exacerbate the brain drain phenomenon from areas with lower economic development. Talented individuals, including researchers and academics, may migrate towards regions with a higher density of knowledge workers and better opportunities. As a result, regions left behind face challenges in maintaining or enhancing their scientific research intensity due to the diminished pool of local talent. Knowledge workers often cluster in regions with established innovation ecosystems, which include universities, research institutions, and industries engaged in R&D activities. While this clustering promotes innovation in these regions, it can negatively affect areas without such ecosystems. The lack of collaboration networks and partnerships makes it difficult for these regions to engage in high-intensity scientific research, limiting their contribution to national and international scientific advancements. Public and private sector funding for scientific research is critical for its development and sustainability. However, with knowledge workers predominantly located in certain regions, funding bodies may prioritize these areas for investment, perceiving them as having a higher return on investment. This prioritization can negatively affect the intensity of scientific research in other regions, which struggle to secure adequate funding for research projects and infrastructure development. Government policies and support mechanisms play a crucial role in shaping the research landscape of a country. A focus on regions with a high density of knowledge workers may lead to policies that do not adequately address the challenges faced by other regions in boosting their scientific research intensity. Without targeted support, these areas may find it difficult to attract and retain researchers, develop research infrastructure, and foster innovation. To mitigate these negative effects and promote a more balanced distribution of scientific research intensity across Italian regions, it is essential to implement policies and initiatives that support regional development, enhance research funding opportunities for less developed areas, and encourage collaboration between regions. Measures such as establishing research centers of excellence in diverse regions, providing incentives for researchers to work in underserved areas, and fostering partnerships between academia, industry, and government across different regions can help bridge the gap and enhance the overall intensity of scientific research in Italy.

6) Machine Learning for the Prediction of Knowledge Workers

To compare the effectiveness of Linear Regression, Polynomial Regression, Decision Trees, Random Forest, Gradient Boosting Machines (GBM), and Support Vector Machines (SVM) for predicting the 2022 knowledge workers percentage based on the data from 2018 to 2021, we'll perform a brief analysis of these algorithms. Given the task involves predicting a continuous variable (the percentage of knowledge workers in 2022), all chosen algorithms are suitable for regression problems. We'll use the data from 2018 to 2021 as features (X) to predict the percentage of knowledge workers in 2022 (y). This prediction task is a regression problem, where we're interested in the accuracy and reliability of the predictions made by each algorithm. We'll evaluate the models based on:

- **R² Score:** Indicates how well the regression predictions approximate the real data points. An R² of 1 indicates a perfect fit.
- **Mean Absolute Error (MAE):** Represents the average error made by the model in predicting the outcome.

The comparison of regression models for predicting the 2022 percentage of knowledge workers in Italian regions, based on data from 2018 to 2021. Here's a table summarizing the performance of the various regression models used to predict the percentage of knowledge workers in Italian regions for 2022.

Model	R ² Score	MAE
Linear Regression	0.92	0.30
Polynomial Regression	-2.77	1.96
Decision Tree	0.46	0.72
Random Forest	0.61	0.56
Gradient Boosting Machines	0.29	0.86
Support Vector Machines	0.39	0.61

Figura 5

This table highlights the superior performance of Linear Regression for this task, with a high R² Score indicating good fit and a low MAE suggesting accurate predictions. The negative R² Score for Polynomial Regression signals a poor fit, indicating that the model does not capture the underlying trends effectively. The other models offer varying degrees of accuracy and fit, with none matching the performance of the Linear Regression model for this particular dataset. We can verify that Linear Regression performed exceptionally well, indicating a strong linear relationship between the past years' data and the target year (2022). This suggests that for this dataset, simpler models can capture the trend effectively. Polynomial Regression significantly underperformed, evidenced by a negative R² Score. This might indicate overfitting to the training data or an inappropriate degree of the polynomial for the nature of this dataset. Decision Tree and Random Forest showed moderate performance, with the Random Forest outperforming the single Decision Tree. This is expected as Random Forests reduce overfitting by averaging multiple decision trees. Gradient Boosting Machines had lower performance compared to other models. While GBMs are powerful, they might require more tuning to capture the patterns in this particular dataset effectively. Support Vector Machines showed modest performance, which might be improved with parameter tuning (like adjusting the C or epsilon values). For the given dataset, Linear Regression emerged as the most effective model for predicting the 2022 knowledge workers percentage. This suggests that the changes in knowledge workers' percentages over the years have a relatively linear progression. However, it's crucial to consider the model's simplicity alongside its performance; while more complex models like Random Forests and GBMs didn't perform as well in this instance, they might offer advantages in different contexts or with datasets that exhibit more complex relationships.

The graph compares the actual versus predicted percentages of knowledge workers in 2022 for each Italian region, based on the Linear Regression model. The blue markers represent the actual percentages, while the red markers, slightly offset for clarity, show the model's predictions (Figure 5).

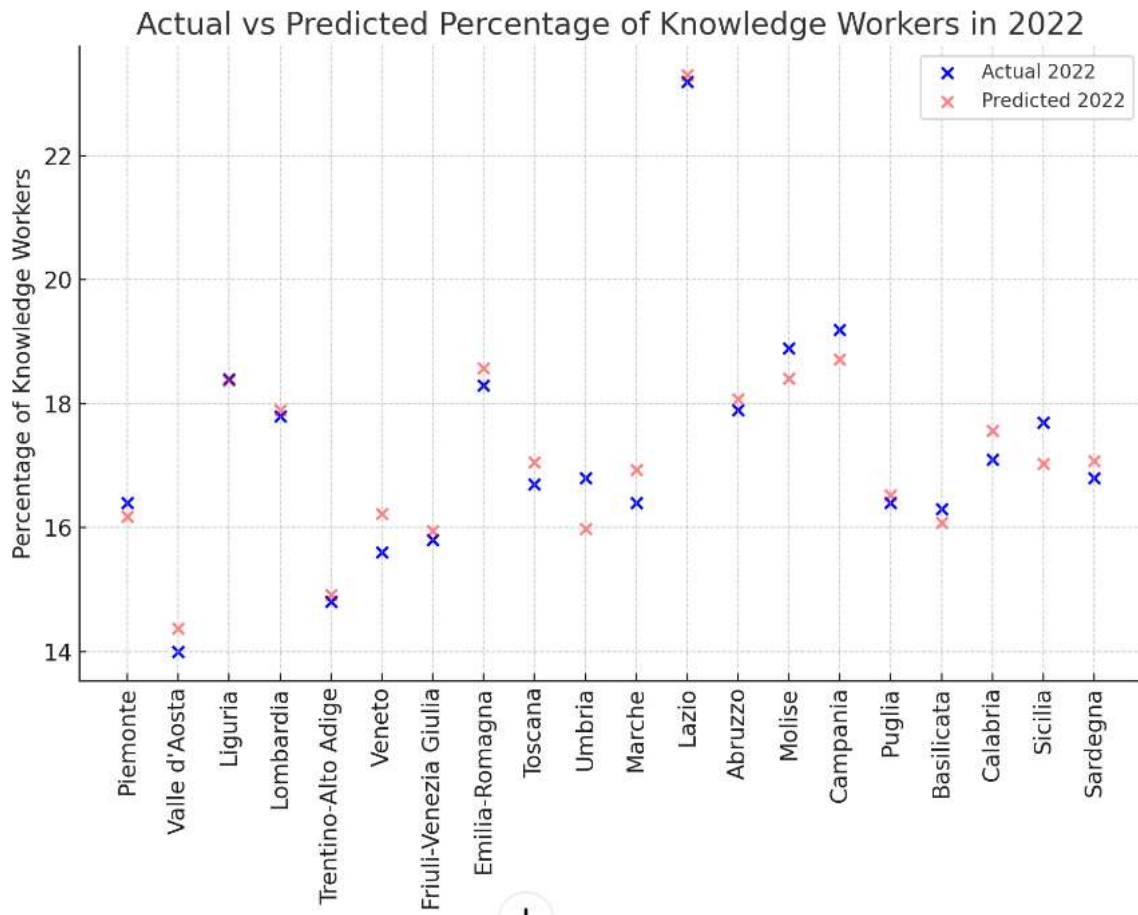


Figure 6. Predictions with Linear Regression. Author's elaboration. Source: ISTAT-BES.

This visualization highlights the Linear Regression model's effectiveness in capturing the trend across the regions, with predictions closely aligning with the actual values for most regions. The model appears particularly adept at predicting within the range of percentages observed, suggesting a strong linear relationship between the historical data and the 2022 outcomes. However, there might be slight deviations in certain regions, which could be attributed to factors not captured by the linear model or variations in data not strictly following a linear trend.

7) Policy Implications

Addressing the needs and potentials of knowledge workers across Italian regions necessitates a multifaceted policy approach that acknowledges both the universal and localized aspects of economic and social development. Firstly, enhancing digital infrastructure is paramount. As the digital economy expands, ensuring robust internet connectivity and access to digital tools is crucial for facilitating knowledge work, particularly in rural or underserved areas. This effort could mitigate regional disparities, allowing knowledge workers regardless of their location to participate fully in the national and global economy. Education and lifelong learning constitute another critical area for policy intervention. Policies should not only emphasize STEM education to build a strong foundation in science, technology, engineering, and mathematics but also integrate arts and humanities to encourage creativity and critical thinking. Such an interdisciplinary approach can produce well-rounded individuals capable of driving innovation in diverse sectors. Furthermore, fostering a culture of innovation through collaboration between academia, industry, and the cultural sector can lead to groundbreaking advancements. Policies that encourage public-private partnerships, facilitate

technology transfer, and provide incentives for research and development can stimulate economic growth and job creation. By leveraging Italy's rich cultural heritage alongside technological innovation, regions can develop unique value propositions that attract and retain knowledge workers. However, these policies are not without limitations. Financial constraints may restrict the ability of regional governments to invest in necessary infrastructure and educational reforms. There's also the challenge of ensuring that policy benefits are equitably distributed to avoid exacerbating existing inequalities. For instance, focusing too heavily on urban centers for infrastructure development could neglect rural areas, widening the digital divide. Additionally, the effectiveness of education and innovation policies may vary significantly between regions due to differences in existing infrastructure, institutional capabilities, and economic contexts. In conclusion, supporting knowledge workers across Italian regions requires a comprehensive policy strategy that balances national priorities with regional needs and potentials. By addressing the limitations and focusing on creating an ecosystem that supports digital infrastructure, education, and innovation, Italy can harness the full potential of its knowledge workers to drive economic growth and regional development.

8) Conclusions

The data analyzed highlights an average growth of knowledge workers in the Italian regions of 3.64% between 2018 and 2022. However, the number of knowledge workers has not grown in all regions. There are regions that have seen a significant decrease in knowledge workers such as Liguria with -1.08%, Tuscany with -4.02%, Lombardy with -4.81%, Trentino Alto Adige with -5.13% , Friuli Venezia Giulia with -5.39% and Valle d'Aosta with -8.5%. On the contrary, the southern regions have seen the value of knowledge workers grow also thanks to the spread of remote working practices that have spread during Covid-19. However, the leading region for the presence of knowledge workers is Lazio which dominates, even constituting an autonomous cluster. Therefore, with exclusive reference to knowledge workers, there is a dominance of Central Italy with respect to which both the North and the South tend to converge. Furthermore, it is very likely that appropriate economic policies relating to education, training, the presence of research centers and adequate structures open to innovation, could make it possible to increase the percentage of knowledge workers, increasing the competitiveness of the Italian economy.

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10) Appendix

LABEL	Variable	Acronym	Relation
A100	Knowledge workers	KW	
A101	Cultural and creative employment	CCE	+
A103	Regular internet users	RIU	+
A104	Availability of at least one computer and Internet connection in the family	AOC	-
A102	Mobility of Italian graduates (25-39 years)	MIG	-
A97	Search intensity	SI	-

Fixed-effects, using 375 observations			
Included 20 cross-sectional units			
Time-series length: minimum 17, maximum 19			
Dependent variable: A100			

Coefficient Std. Error t-ratio p-value

const	0.722431	0.329745	2.191	0.0291	**
A97	-0.502527	0.220851	-2.275	0.0235	**
A101	4.46513	0.0889430	50.20	<0.0001	***
A102	-0.110569	0.0114032	-9.696	<0.0001	***
A103	0.162141	0.0239483	6.770	<0.0001	***
A104	-0.143179	0.0241196	-5.936	<0.0001	***

Mean dependent var	4.600800	S.D. dependent var	7.699057
Sum squared resid	775.5789	S.E. of regression	1.488603
LSDV R-squared	0.965015	Within R-squared	0.964879
LSDV F(24, 350)	402.2645	P-value(F)	1.7e-238
Log-likelihood	-668.3551	Akaike criterion	1386.710
Schwarz criterion	1484.883	Hannan-Quinn	1425.686
rho	0.622010	Durbin-Watson	0.798707

Joint test on named regressors -

Test statistic: $F(5, 350) = 1923.11$

with p-value = $P(F(5, 350) > 1923.11) = 4.97061e-252$

Test for differing group intercepts -

Null hypothesis: The groups have a common intercept

Test statistic: $F(19, 350) = 4.33122$

with p-value = $P(F(19, 350) > 4.33122) = 1.02676e-08$

Random-effects (GLS), using 375 observations

Using Nerlove's transformation

Included 20 cross-sectional units

Time-series length: minimum 17, maximum 19

Dependent variable: A100

	<i>Coefficient</i>	<i>Std. Error</i>	<i>z</i>	<i>p-value</i>	
const	0.758609	0.358433	2.116	0.0343	**
A97	-0.504293	0.200985	-2.509	0.0121	**
A101	4.46363	0.0876556	50.92	<0.0001	***
A102	-0.113348	0.0110799	-10.23	<0.0001	***
A103	0.160539	0.0232194	6.914	<0.0001	***
A104	-0.142410	0.0233788	-6.091	<0.0001	***

Mean dependent var	4.600800	S.D. dependent var	7.699057
Sum squared resid	962.0312	S.E. of regression	1.612478

Log-likelihood	-708.7496	Akaike criterion	1429.499
Schwarz criterion	1453.061	Hannan-Quinn	1438.853
rho	0.622010	Durbin-Watson	0.798707

'Between' variance = 0.526891
'Within' variance = 2.06821
mean theta = 0.583812
Joint test on named regressors -
Asymptotic test statistic: Chi-square(5) = 9724.29
with p-value = 0
Breusch-Pagan test -
Null hypothesis: Variance of the unit-specific error = 0
Asymptotic test statistic: Chi-square(1) = 65.0463
with p-value = 7.31593e-16
Hausman test -
Null hypothesis: GLS estimates are consistent
Asymptotic test statistic: Chi-square(5) = 10.4924
with p-value = 0.0624267

Pooled OLS, using 375 observations
Included 20 cross-sectional units
Time-series length: minimum 17, maximum 19
Dependent variable: A100

	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-ratio</i>	<i>p-value</i>	
const	0.864225	0.316640	2.729	0.0066	***
A97	-0.461295	0.167730	-2.750	0.0062	***
A101	4.45733	0.0920934	48.40	<0.0001	***
A102	-0.124161	0.0113114	-10.98	<0.0001	***
A103	0.155038	0.0231161	6.707	<0.0001	***
A104	-0.140362	0.0232140	-6.046	<0.0001	***

Mean dependent var	4.600800	S.D. dependent var	7.699057
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Sum squared resid	957.9356	S.E. of regression	1.611220
R-squared	0.956789	Adjusted R-squared	0.956204
F(5, 369)	1634.117	P-value(F)	3.3e-249
Log-likelihood	-707.9497	Akaike criterion	1427.899
Schwarz criterion	1451.461	Hannan-Quinn	1437.253
rho	0.709750	Durbin-Watson	0.690514

WLS, using 375 observations					
Included 20 cross-sectional units					
Dependent variable: A100					
Weights based on per-unit error variances					

	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-ratio</i>	<i>p-value</i>	
const	0.627645	0.271334	2.313	0.0213	**
A97	-0.273138	0.133263	-2.050	0.0411	**
A101	4.59605	0.0696333	66.00	<0.0001	***
A102	-0.133928	0.0110481	-12.12	<0.0001	***
A103	0.102047	0.0201232	5.071	<0.0001	***
A104	-0.0941250	0.0202347	-4.652	<0.0001	***

Statistics based on the weighted data:					
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Sum squared resid	362.2639	S.E. of regression	0.990831
R-squared	0.972050	Adjusted R-squared	0.971671
F(5, 369)	2566.617	P-value(F)	4.2e-284
Log-likelihood	-525.6233	Akaike criterion	1063.247
Schwarz criterion	1086.808	Hannan-Quinn	1072.601

Statistics based on the original data:					
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Mean dependent var	4.600800	S.D. dependent var	7.699057
Sum squared resid	982.7089	S.E. of regression	1.631921

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