# Analyzing Regional Disparities in E-Commerce Adoption Among Italian SMEs: Integrating Machine Learning Clustering and Predictive Models with Econometric Analysis

Leogrande, Angelo and Drago, Carlo and Arnone, Massimo

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# Analyzing Regional Disparities in E-Commerce Adoption Among Italian SMEs: Integrating Machine Learning Clustering and Predictive Models with Econometric Analysis

Angelo Leogrande ^, Carlo Drago°, Massimo Arnone

^LUM University Giuseppe Degennaro leogrande.cultore@lum.it

°Associate Professor at Niccolò Cusano University, carlo.drago@unicusano.it

*Researcher University of Catania, Department of Economics and Business massimo.arnone@unict.it

*Abstract*

The article explores the diffusion of online sales tools among Italian enterprises with at least ten employees, considering regional inequalities through methods that help address economic policy. The study gives an overall assessment of the adoption of e-commerce among Italian SMEs, using multiple methods that help to identify regional disparities and provide insight for policymakers. The data were obtained from the ISTAT-BES database. Analysis was applied using the k-Means machine learning algorithm by comparing the Silhouette coefficient vs. the Elbow method. The elbow method reveals greater expository capacity, and the optimal number of clusters equals 3. The econometric analysis used the following methods: Panel Data with Fixed Effects, Panel Data with Random Effects, Weighted Least Squares-WLS, and Dynamic Panels at 1 Stage. The results show that cultural and creative employment and regular internet users are positively associated with SMEs active in e-commerce while negatively associated with the family's availability of at least one computer and internet connection. Finally, the article compares different machine learning algorithms to predict the future value of SMEs active in e-commerce. The results are discussed critically.

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

Keywords: e-Commerce, Small and Medium Enterprises, Regional Inequalities, Panel Data, k-Means, Machine-Learning.

## 1. Introduction

The article mainly focuses on regional differences, unveiling the socioeconomic and technological factors determining e-commerce adoption by comparing the Italian regions. Besides, it determines the effectiveness of agglomerative algorithms with k-means clustering, optimized with the silhouette coefficient and elbow method, on patterns and grouping by regions. In contrast, based on panel econometric models, the former examines technological and innovative determinants fostering the adoption of e-commerce. Further, there is an examination of the comparison among different machine learning algorithms in forecasting the future trend of e-commerce adoption and rounds off with the policy recommendations for the economic policy measures of the future. (Polenzani, et al., 2021; Gherghina et al., 2021; Belisari et al., 2020). The article's methodology is relevant, attractive, and innovative and covers the comprehensiveness of analysis regarding e-commerce adoption among Italian SMEs from different regions. The article involves an analytical technique with static analysis, clustering with algorithms like k-Means optimized with the Silhouette Coefficient and the Elbow Method, panel econometric modeling, and comparisons between various machine learning algorithms to predict future trends. With these techniques, it will be possible to obtain a comprehensive view of the phenomenon from the distribution point of view in the Italian regions by performing comparative statics and clustering. Afterward, the econometric analysis makes verifying the existence of relevant relationships in the estimated model possible. In contrast, prediction via machine learning algorithms enables making estimates on what the future trend of the variable analyzed might be. This multidisciplinary approach provides an as-eye view of regional inequalities in adopting e-commerce within the region. It delivers substantial value added to formulating evidence-based policies at the national and local levels. This article enriches the present literature on the geographical pattern of e-commerce diffusion across Italian regions.

The main research question in the article involves regional inequalities in e-commerce adoption by SMEs in Italy and some of the socioeconomic and technological variables explaining these disparities. In other words, it is an attempt to find out how regional differences in Italy affect the adoption of e-commerce by SMEs through different analytical methods in identifying probable causes and determining recommendations for economic policies. This article combines static analysis, clustering techniques, econometric modelling, and machine learning predictions. This methodology is comprehensive in that it explains, with nuances, regional disparities in e-commerce adoption prevailing at present and also provides practical insights for policymakers to overcome such disparities. Furthermore, focusing on current trends and future projections would be of value in guiding digital transformation efforts across Italian regions.

Essentially, this paper is one's deep analysis of the dynamics in web sales activities at those firms with at least ten employees targeting end customers—these include, of course, those located in various Italian regions. The question focuses on analysing how differing socioeconomic landscapes and digitalization and technological innovation levels in these regions shape these companies' digital commerce strategies and performance. Against this backdrop, a substantial regional gap within Italy is projected. That is, between the digital advances present in the northern Italian regions and the traditionally less digitalized regions in Southern Italy, the study explores those factors that influence success rates in digital commerce among them within the respective regions. The research has adopted a mixed-method approach to explicate this phenomenon. A mix of quantitative, data-based, static analyses, clustering, econometric techniques, and machine-learning algorithms is applied. These expand more on the experience of companies, challenges, and strategies of doing business in the digital commerce landscape within regional-context-sensitive environments. With this interpretation, the research aims to discover the subtle and not direct ways in which regional disparities impinge on the adoption and effectiveness of web sales channels. Identification of the main barriers hampering efforts at digital transformation among Italian companies, together with facilitators that help support their path toward successful digital integration. The detailed research is expected to provide valuable insight into adjustments needed in the economic policy for business ventures to thrive within the digital marketplace. It thus hopes to delineate how economic policy will drive companies to exploit regional strengths and rise above local challenges to unlock the full potential of digital trade. The article aims to draw up some practical recommendations that could be useful in bridging the digital divide between Italian regions so businesses anywhere in the country can flourish in a fast-changing digital environment (Caputo et al., 2022; Bălăcescu et al., 2023; Mazzanti et al., 2022; Cassetta et al., 2020). The first stage in the study uses static analysis to lay a strong foundation for understanding the current status of e-commerce adoption for SMEs. The description accords with identifying baseline trends and patterns in e-commerce adoption by SMEs and establishes a platform for further advanced analyses—in this case. The research applies clustering techniques with the specific use of k-means clustering; the research optimally applies the Silhouette Coefficient and the Elbow Method. This will enable categorizing regions into various classes concerning similarities in the measured e-commerce adoption metrics. In this light, clustering may offer insight into the regional groups that might otherwise have shown common socioeconomic or technological characteristics that influence their digital business activity. The research then models, in econometric fashion, the question of the factors that drive e-commerce adoption. Its panel data econometrics looks at how the various technological and innovation factors explain the observed patterns. This approach will enable the identification of relationships and, hence, the evaluation of the impact of some variables over time and across various

regions. This article uses machine-learning algorithms to predict further trends in SMEs' adoption of e-commerce. By testing and comparing various algorithms, this research predicts possible developments and evaluates the effectiveness and accuracy of various predictive models. The overall view of this research is very much oriented to the future and draws very useful projections for policy formulation. This integrated approach allows a granular and detailed account of how regional disparities shape digital commerce activities among SMEs in Italy. Such a comprehensive study was not conducted in the existing literature; therefore, this is a significant, original contribution to this place (Punhani, et al., 2022; Leogrande et al., 2022; Dasig et al., 2022; Siagian et al. 2021).

It is particularly relevant in the context of digital transformation and regional economic development in Italy. As Italy moves forward in the labyrinth of the fast-changing digital economy, understanding what factors drive or hinder e-commerce adoption among SMEs would be necessary for shaping effective policies. It will contribute some valuable, timely, and pragmatic insight into the consumption patterns of digital services, especially by policymakers in policies that target digital inclusion or focus on reducing regional disparities in access, adoption, and use of digital infrastructure and technologies in different parts of the country. Regional disparities in Italy exist in digital infrastructure, technology adoption rate, and general development. These disparities have created an uneven playing field, where some regions are better poised to leverage the benefits of e-commerce while others, due to various socioeconomic and infrastructural challenges, are not. In this respect, the article has vividly mapped out the current state of e-commerce adoption across the country by analyzing these differences in using e-commerce and identifying the strengths and weaknesses of each region. This would give an overview and help design focused interventions so that those lagging regions may catch up with their more advanced counterparts. In this sense, the findings of the study are most opportune in the post-COVID-19 era, where the pandemic hastened the shift toward digital platforms. With lockdowns imposing the necessity to go online on businesses if they were to survive, e-commerce became not just an option but a need. This really underlines how significant digital preparedness could be, also bringing down quite hard in demonstrating the vulnerabilities of regions without such preparedness in the event of any such transition. Therefore, the focus of this article on factors that influence e-commerce adoption is very well placed to assist policymakers with urgent needs in driving economic recovery and growth through digital means. In particular, the insight obtained from this study can inform strategic investments in digital infrastructure and education, ensuring that all regions can participate in and benefit from the digital economy regardless of their starting point. It thus serves the more general purpose of all-inclusive economic growth, in which the fruits of digital transformation are effectively redistributed among regions to reduce disparities and

give a foothold for more balanced economic development all over Italy (Lepore et al., 2021; Marino et al., 2023; Bellandi, 2020; Penco et al., 2022).

The article continues as follows: the second section shows the literature analysis, the third section contains the static analysis, the fourth section presents the clustering with the k-Means algorithm, the fifth section shows the results of the econometric model, the sixth section presents the machine learning algorithms used for prediction, the seventh section contains the economic policy implications, and the eighth section concludes.

## 2. Literature Review

Hussain et al. (2022) explore the impact of e-commerce on SME performance, emphasizing the moderating role of entrepreneurial competencies. This study suggests that entrepreneurial skills significantly enhance the benefits of e-commerce for SMEs, indicating that not just the technological infrastructure but also the human capital is crucial for leveraging e-commerce advantages. The moderating role of entrepreneurial competencies is a valuable insight, underscoring the nature of e-commerce benefits. Kim and Lim (2022) investigate SMEs' international dynamic marketing capabilities from emerging markets through e-commerce. Their findings highlight how SMEs can leverage e-commerce for international marketing, suggesting a strategic pathway for emerging-market SMEs to globalize efficiently. This perspective complements the first study by focusing on the external, market-facing capabilities enabled by e-commerce. Hussain et al. (2020) delve into organizational and environmental factors affecting SME performance, with e-commerce serving as a mediating role. This study broadens the scope by considering the ecosystem within which SMEs operate, suggesting that e-commerce effectiveness is contingent on both internal organizational factors and the external business environment. The mediating role of e-commerce in this relationship is a critical insight, suggesting e-commerce as a tool for SMEs to navigate their operational context. Yang et al. (2022) focus on the role of complementary resources and external readiness in enhancing SME performance through e-commerce. By highlighting the importance of external readiness and the functionality of e-commerce platforms, this study adds to the discourse on the prerequisites for SMEs to successfully exploit e-commerce, suggesting a need for a strategic alignment between SME resources and their e-commerce initiatives. Pan et al. (2023) examine SME participation in cross-border e-commerce as a mode of entry into foreign markets, questioning its role as a driver of innovation. This study challenges the assumption that e-commerce inherently facilitates innovation,

suggesting that its impact on innovation depends on how SMEs engage with e-commerce for internationalization. This nuanced view presents e-commerce not as a universal solution but a strategic tool that can offer various benefits, including innovation, depending on its application.

Syafrizal (2021) investigates the development of a web-based online marketing system for SMEs, emphasizing the role of technological infrastructure in enabling SMEs to compete in the digital marketplace. This study highlights the importance of accessible and user-friendly e-commerce platforms for SME engagement in online marketing, suggesting that technology development directly influences SMEs' ability to leverage e-commerce. Almtiri et al. (2023) delve into the application of e-commerce technologies to boost the operational success of SMEs. By focusing on the technological aspect of e-commerce, this work underlines the critical role of adopting advanced e-commerce solutions for enhancing SME efficiency and competitiveness. The emphasis on technology application provides a forward-looking perspective on the potential for e-commerce to transform SME operations. Cheong et al. (2020) conducted a systematic literature review to assess the impact of COVID-19 on SMEs' adoption of e-commerce. This study is particularly relevant for understanding the pandemic as a catalyst for digital transformation among SMEs. It offers insights into SMEs' accelerated adoption of e-commerce in response to the challenges posed by COVID-19, highlighting the resilience and adaptability of SMEs in times of crisis. Hasan and Mardhani (2021) present an overview of e-commerce adoption among Indonesian SMEs, providing a geographical and cultural context to the discussion. This study sheds light on the challenges and opportunities Indonesian SMEs face in embracing e-commerce, offering a nuanced view that considers the local business ecosystem, infrastructure, and digital literacy levels. Prasetya et al. (2022) explore optimizing digital marketing strategies through e-commerce to increase sales for Batik Cikadu, a specific SME in Indonesia. This case study approach allows for a detailed examination of practical strategies and outcomes associated with e-commerce adoption, illustrating the tangible benefits of digital marketing for SME sales and brand visibility.

Nurjaman (2022) discusses the empowerment of e-commerce among SMEs in Indonesia, focusing on the capacity-building aspect of digital platforms. This study underlines the significance of e-commerce as a tool for enhancing SMEs' operational capabilities and market reach in a developing country context. The emphasis on empowerment highlights the socio-economic benefits of e-commerce adoption beyond mere technological adoption. Özbek et al. (2024) examine the institutional theory perspective on e-commerce adoption by internationalizing retail SMEs, exploring the responses to mimetic pressures. This research provides insights into how SMEs navigate institutional pressures to adopt e-commerce, suggesting that external benchmarks and perceived

industry standards influence the decision-making process. This perspective adds depth to understanding e-commerce adoption, framing it within the broader context of institutional norms and pressures. Guo et al. (2023) delve into the intersection of e-commerce, supply chain finance, and green innovation for SMEs. By linking e-commerce with sustainable practices within the supply chain, this study presents a novel angle on how e-commerce can contribute to both financial performance and environmental sustainability. The role of green innovation underscores the potential for e-commerce to support broader sustainability goals. Demiroglu (2021) views e-commerce as a developmental tool for small businesses, emphasizing its role in facilitating business growth and adaptation to market dynamics. This work contributes to the discourse by presenting e-commerce as a critical enabler of small business development, highlighting the transformative potential of digital platforms in enhancing competitiveness and innovation. Salazar and Mauricio (2024) provide a comprehensive review of SME e-commerce performance factors and metrics over a decade, offering a longitudinal perspective on how e-commerce impacts SME performance. This study contributes to a deeper understanding of the effectiveness of e-commerce strategies, identifying key performance indicators and success factors. The longitudinal approach allows for an assessment of evolving trends and the long-term impact of e-commerce on SMEs.

Octavia et al. (2020) investigate the effect of e-commerce adoption on entrepreneurial and market orientations in SME business performance. This study underscores the importance of strategic orientations as mediators in the relationship between e-commerce adoption and business performance. By linking e-commerce adoption to entrepreneurial and market orientations, the research highlights how digital platforms can enhance business agility and market responsiveness, leading to improved performance outcomes. Wimpertiwi et al. (2023) focus on the mediation role of e-commerce capability in the relationship between strategic orientation and business performance, including hybrid channel effectiveness. This empirical analysis extends the understanding of how e-commerce capabilities enable SMEs to translate strategic orientations into performance gains. By examining hybrid channels, the study contributes insights into integrating online and offline operations, emphasizing the importance of a cohesive strategy for leveraging e-commerce. Ilham and Ratnamiasih (2021) delve into the impact of e-commerce and competence on business performance, specifically focusing on implementing e-commerce by university students. This empirical study provides a unique perspective on the role of individual competencies in maximizing the benefits of e-commerce for business performance. Highlighting the intersection between education, digital literacy, and e-commerce adoption, this research underscores competence's critical role in effectively leveraging e-commerce technologies. Sun (2021) explores the relationship between internet usage and SME participation in exports, providing evidence of how digital connectivity facilitates SME

access to international markets. This study broadens the scope of e-commerce research by linking internet accessibility to export activities, suggesting that digital platforms can be a significant enabler for SME internationalization. The focus on exports adds an essential dimension to the discourse on e-commerce, highlighting the potential for digital technologies to bridge geographical barriers and open new market opportunities. Riadi et al. (2022) assess the benefits of e-commerce for small enterprises before and during the COVID-19 pandemic, offering insights into how digital platforms have supported business continuity and resilience. This research highlights the accelerated adoption and increased reliance on e-commerce as a survival strategy during crises by comparing pre-pandemic and pandemic periods. This study emphasizes the role of e-commerce in enabling business adaptability and continuity, particularly in the face of unprecedented challenges.

Yun et al. (2020) explore the sustainability condition of open innovation, mainly through the dynamic growth of Alibaba from an SME to a large enterprise. This study highlights the critical role of open innovation in sustaining the growth and transformation of businesses in the digital age. By focusing on Alibaba, a prominent success story, the research provides valuable insights into how open innovation practices can support scalability and sustainability in the e-commerce sector. However, the generalizability of findings from a singular case study, mainly one as unique as Alibaba, to other SMEs could be limited. Chang et al. (2023) delve into the optimal combination of platform channel contracts and guarantee financing strategy in the e-commerce market. This research contributes to understanding the financial mechanisms that underpin e-commerce operations, offering a quantitative analysis of how e-commerce platforms can structure contracts and financing strategies to optimize performance. While this study adds depth to the financial aspect of e-commerce, its technical nature and focus on optimization models may limit its applicability for practitioners with a strong finance or operations research background. Wang (2024) examines the use of artificial intelligence to analyze SME e-commerce utilization and growth strategies. This forward-looking study underscores the potential of AI in enhancing the strategic decision-making of SMEs in the e-commerce domain. By demonstrating how AI can be leveraged to identify growth opportunities and optimize e-commerce strategies, the study points to the future of digital entrepreneurship. The challenge remains in the accessibility of such AI tools for SMEs and the need for digital literacy to exploit this potential fully. Harto and Komalasari (2020) focus on optimizing online internet marketing platforms for SMEs, specifically Little Rose Bandung. This case study offers practical insights into how SMEs can leverage online platforms for marketing and sales enhancement. While the localized context provides an in-depth understanding, the scalability and applicability of these strategies to other SMEs in different contexts or industries may require further exploration. Priambodo et al. (2021) assess the e-commerce readiness of the creative industry during the COVID-19 pandemic in Indonesia. This

timely study highlights the challenges and opportunities the creative industry faces in transitioning to e-commerce amidst the pandemic. By providing an overview of readiness levels, the research sheds light on the factors that enable or hinder e-commerce adoption among creative SMEs. While insightful, the specificity to the COVID-19 context and the creative industry in Indonesia may limit the study's broader applicability.

Goldman et al. (2021) examine the strategic orientations and digital marketing tactics of SMEs engaged in cross-border e-commerce, comparing practices in developed and emerging markets. This study is valuable for understanding how strategic choices in digital marketing are adapted to different market conditions and highlighting the nuanced approaches required for success in diverse environments. However, the study may need to fully capture the rapidly evolving landscape of digital marketing and e-commerce, necessitating ongoing research to keep pace with technological advancements and market dynamics. Rawash (2021) focuses on the adoption of e-commerce by SMEs in Jordan, using the Technology-Organization-Environment (TOE) model. This study provides insights into the factors influencing e-commerce adoption in a specific cultural and economic context, contributing to the literature on technology adoption in SMEs. While offering valuable localized insights, extending the findings to broader or different contexts may require additional consideration of regional and sectoral specificities. Tong and Gong (2020) discuss the impact of COVID-19 on SME digitalization in Malaysia, providing an empirical look at how the pandemic has accelerated the move towards digital business models. This research highlights the role of external shocks in digital transformation but may benefit from a longitudinal approach to assess the sustainability of these changes post-pandemic. Ismail and Masud (2020) explore the prospects and challenges of improving e-commerce connectivity in Malaysia, contributing to understanding infrastructural and regulatory needs for facilitating e-commerce. This study is crucial for policymakers and business leaders in strategizing e-commerce development but might need to be complemented with stakeholder perspectives. Parvin et al. (2022) analyze the impact of introducing e-commerce on logistics providers, a case study focusing on SMEs. By shedding light on a specific aspect of the e-commerce ecosystem, this research offers practical insights into how e-commerce adoption can transform traditional business operations. The case study approach provides in-depth analysis but might limit generalizability across different sectors and geographies.

Barata et al. (2023) explore the determinants of e-commerce, artificial intelligence (AI), and agile methods in SMEs. This study comprehensively examines how technological and methodological advancements can significantly impact SME efficiency and adaptability. By integrating AI and agile methodologies with e-commerce strategies, SMEs can enhance their competitiveness and innovation

capacity. However, the study may need to fully address SMEs' challenges in adopting these advanced technologies and methodologies, including financial and human resource constraints. Kosobutskaya et al. (2020) discuss the advantages and opportunities for developing small business e-commerce in the B2B sector. This research underscores the potential for SMEs to leverage e-commerce for growth and expansion in the B2B realm, highlighting the strategic benefits of digital platforms. While offering valuable insights, the study might benefit from a more detailed examination of the barriers to e-commerce adoption in the B2B sector, such as integration with existing business processes and systems. Awe and Ertemel (2021) investigate the enhancement of micro-small businesses in The Gambia through digitalization, focusing on youth entrepreneurs' perceptions, usage, and inhibitors of e-commerce technology. This paper offers critical insights into the role of digital technologies in empowering entrepreneurs in developing countries. It sheds light on the opportunities and challenges young entrepreneurs face in adopting e-commerce, emphasizing the need for supportive policies and infrastructure. However, the study's focus on a specific demographic and geographical location may limit its generalizability. Kadir and Shaikh (2023) examine the effects of e-commerce businesses on SMEs, mainly through media techniques and technology. The study highlights the importance of digital marketing and social media in enhancing the visibility and reach of SMEs in the e-commerce landscape. Kirom et al. (2022) analyze e-commerce strategies for MSME innovation development. This timely research addresses how MSMEs can navigate post-pandemic challenges through innovative e-commerce strategies. It provides a strategic framework for MSMEs to adapt to changing market demands and consumer behaviors.

Gao et al. (2023) assess the impact of e-commerce and digital marketing adoption on MSMEs' financial and sustainability performance during the COVID-19 pandemic through an empirical study. This research is valuable for its timely investigation into how digital strategies have influenced business performance in a crisis context, highlighting the resilience and adaptability afforded by digital tools. However, it would be beneficial if the study also explored the long-term sustainability of these adaptations post-pandemic and the potential challenges businesses may face as the global economy transitions to a new normal. Lestari et al. (2021) delve into the differential impact of the COVID-19 pandemic on the performance of small enterprises that are e-commerce adopters versus non-adopters. By contrasting these two groups, the study provides evidence of the protective effects of e-commerce adoption against the pandemic's adverse impacts. This study's focus offers critical insights but may benefit from a broader consideration of the various factors influencing e-commerce adoption and performance beyond the pandemic, including technological, managerial, and environmental barriers. Fan and Ouppara (2022) examine how SMEs can survive disruption and uncertainty through digital transformation using case studies. This contribution is beneficial for its

practical insights into how businesses have navigated the challenges posed by the pandemic, showcasing specific strategies and outcomes of digital transformation efforts. While rich in practical implications, the generalizability of case study findings to a broader SME audience may require further empirical validation. Madias and Szymkowiak (2022) focus on the functionalities of social commerce SMEs use during the pandemic. This study highlights the innovative use of social media platforms for commerce, underscoring the importance of social commerce as a tool for business continuity and customer engagement during crises. Kujala and Halonen (2020) investigate business growth in small businesses through open-source e-commerce and ERP (Enterprise Resource Planning) systems. This research offers an exciting perspective on the technological underpinnings necessary for e-commerce success, emphasizing the cost-effectiveness and flexibility of open-source solutions.

Costa and Castro (2021) argue that e-commerce represents an essential strategy for SMEs to enhance their resilience and survivability, especially in challenging times such as during the COVID-19 pandemic. This study provides a valuable perspective on e-commerce as a critical tool for business continuity, emphasizing the urgent need for SMEs to adopt digital platforms. Suryani et al. (2022) explore the impact of digital literacy and e-commerce adoption on SME performance, focusing on the online-to-offline (O2O) business model. This study contributes to understanding how digital skills and the strategic use of e-commerce can enhance SME competitiveness and market reach. Ushada et al. (2024) delve into the trust decision-making process of Indonesian food and beverage SMEs in adopting Industry 4.0 technologies. By modelling trust factors, this research sheds light on the psychological and social dimensions influencing technology adoption, offering a novel angle on the challenges of digital transformation. Khodjayev (2021) examines the efficiency of modern ICT in small business operations, highlighting the transformative potential of technology for improving business processes and customer engagement. This contribution underscores the importance of ICT for operational efficiency. Singh et al. (2023) investigate the relationship between e-commerce adoption, digital marketing strategies, online customer engagement, and the performance of small businesses. This study provides comprehensive insights into how a coherent digital strategy can significantly impact SME performance, emphasizing the role of technology infrastructure and online engagement.

Ardiansah et al. (2021) examine the impact of e-commerce on accounting information systems and organizational performance. This study provides insights into how digital commerce integration can enhance the accuracy, efficiency, and overall performance of accounting systems within organizations. It underscores the potential for e-commerce to drive operational improvements. Sidek

et al. (2020) explore the factors influencing awareness of e-commerce among small businesses in Kelantan. By focusing on proclivity factors, the research contributes to understanding the barriers to e-commerce adoption and the importance of raising awareness among SMEs. D AL-TAYYAR et al. (2021) address the challenges and obstacles facing SMEs in adopting e-commerce in developing countries with a case study in Saudi Arabia. This research highlights critical barriers such as infrastructure, regulation, and digital literacy, offering a comprehensive overview of SMEs' hurdles in digital transformation.

The focus on developing countries is crucial, though comparative studies with SMEs in developed countries could provide additional insights into universal vs. region-specific challenges. Setiawan et al. (2023) investigate the impact of e-commerce on the performance of micro and small industries, considering firm size as a moderating factor. This study provides a nuanced view of how e-commerce benefits can vary based on firm size, suggesting that smaller firms may face distinct challenges or realize different advantages from e-commerce adoption. Susanty et al. (2020) apply the push-pull-mooring framework to e-commerce adoption in SMEs. This framework offers a comprehensive approach to understanding the factors that drive businesses towards or away from e-commerce adoption, including internal motivations, external pressures, and the ease of transitioning to digital platforms. While providing a robust theoretical model, empirical studies applying this framework in various contexts would enrich the understanding of its applicability across different sectors and cultural settings.

| Macro-Theme | References |
|---|---|
| Tourism Attraction and Regionality | Algieri and Álvarez, 2023; Franch et al., 2017; Bentivogli et al., 2019; Billé et al., 2023; Brunetta et al., 2007; Burlina et al., 2023; Calignano and Quarta, 2015; Carmela, 2020; Marino et al., 2023; Orusa and Borgogno Mondino, 2021; Vergamini et al., 2019; Podestà, 2017 |
| E-Commerce and Digital Transformation | Alimonti et al., 2020; Almtiri et al., 2023; Ardiansah et al., 2021; Barata et al., 2023; Barkatullah, 2018; Caputo et al., 2022; Chang et al., 2023; Chen et al., 2021; Chawla and Kumar, 2022; Chotimah, 2019; Costa and Castro, 2021; D'Adamo et al., 2021; Dai et al., 2022 |
| Technological Innovation and SMEs | Avdeeva, 2021; Awe and Ertemel, 2021; Cirillo et al., 2023; Dinis et al., 2023; Elia et al., 2021; Frick, 2023; Georgescu et al., 2022; Guo et |

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|---|---|
| | al., 2023; He and Li, 2023; Hussain et al., 2022; Kadir and Shaikh, 2023; Khodjayev, 2021; Kim and Lim, 2022; Patti and Schifilliti, 2023 |
| Digital Literacy and Digital Divide | Arianti, 2023; Gallardo, 2019; Gutierrez-Angel et al., 2022; Di Pietro, 2021; Lestari et al., 2021; Steyn, 2018; van Kessel et al., 2022; Natale and Piccininno, 2015; Fox et al., 2016 |
| Machine Learning and AI | Ashari et al., 2023; Belkadi et al., 2021; Bentéjac et al., 2021; Chaurasia and Pal, 2020; Dasig et al., 2022; de Araujo and Reinhard, 2019; Dinh et al., 2019; Leogrande et al., 2022; Mohapatra et al., 2022; Nabipour et al., 2020; Patel et al., 2022; Punhani et al., 2022; Zhou, 2021 |
| Covid-19 and Economic Impacts | Bellandi, 2020; Cheong et al., 2020; Harto and Komalasari, 2020; Hasan and Mardhani, 2021; Penco et al., 2022; Priambodo et al., 2021; Sun, 2021; Tong and Gong, 2020; Ilham and Ratnamiasih, 2021 |

## 3. Data

To evaluate the determinants of companies with at least ten employees that use online sales, we used the Istat-BES database. The Istat-BES database is composed of various subcategories. In particular, the relationships between SMEs and the innovation system were investigated through the use of the variables indicated in Table 1 below.

Table 1. List of variables with description and sources.

| Variable | Acronym | Definition | Source |
|---|---|---|---|
| Companies with at least 10 employees with web sales to end customers | SME | Refers to businesses that have a minimum of 10 full-time or equivalent part-time employees and engage in direct online sales to the final consumers of their products or services. These companies utilize digital platforms, such as e-commerce websites, mobile apps, or other online marketplaces, to facilitate transactions between the business and its end customers, bypassing traditional brick-and-mortar interactions. The employee threshold of at least 10 individuals distinguishes these companies from micro-enterprises, suggesting they have reached a level of operational complexity and scale that typically involves structured management, more significant resource allocation, and potentially broader market reach. The emphasis on "web sales" underscores the importance of the internet as a primary sales channel, where transactions are initiated, managed, and completed through digital means. These sales can include a wide range of products, from physical goods like electronics, clothing, or groceries to digital products or services such as software, online subscriptions, or consultancy services. The term "end customers" specifies that the sales are directed to the final consumers rather than to other businesses or intermediaries. This focus highlights the B2C (Business-to-Consumer) nature of the transactions, where the ultimate user of the product or service is the buyer (Dai et al., 2022; Saha et al., 2018; Konradt, et al., 2016; Farell et al., 2018). | ISTAT-BES |
| Cultural and creative employment | CCE | Cultural and creative employment refers to jobs that are directly or indirectly associated with the production, distribution, and consumption of cultural goods and services, as well as those in the broader creative industries. This form of employment encompasses a wide range of occupations | ISTAT-BES |

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|---|---|---|---|
| | | that contribute to the creation and dissemination of artistic, cultural, and creative content. At its core, cultural and creative employment includes individuals working in traditional cultural sectors such as performing arts, visual arts, literature, music, heritage, and museums. These sectors are often characterized by activities that preserve, express, and celebrate cultural identity and heritage. Workers in these fields might include musicians, actors, writers, painters, curators, and archivists, among others. Beyond the traditional arts, cultural and creative employment also spans the broader creative industries. This includes jobs in sectors like advertising, design, architecture, film and video production, fashion, broadcasting, publishing, and software development. Innovation, creativity, and the generation of intellectual property typically drive these industries. They often intersect with technology, media, and commerce, creating a vibrant and dynamic economic sector. Employees in these fields might work as graphic designers, filmmakers, architects, fashion designers, software developers, or media producers. A mix of full-time, part-time, freelance, and project-based work, reflecting the dynamic and sometimes precarious nature of the creative economy, often characterizes cultural and creative employment. It plays a significant role in fostering cultural diversity, supporting social cohesion, and contributing to economic growth (Snowball et al., 2017; Dasgupta and Clini, 2023; Klein et al., 2021; Shafi et al.; 2020). | |
| Regular internet users | RIU | Regular internet users refers to individuals who consistently access and use the internet for various activities, typically on a daily or weekly basis. This group includes people who rely on the internet as a central part of their daily lives, whether for work, education, communication, entertainment, or other purposes. Regular internet users engage in a broad spectrum of online activities. These can range from browsing websites, using social media platforms, streaming videos, and playing online games, to more functional tasks such as managing finances, shopping, and accessing government services. The frequency and variety of these activities distinguish regular users from occasional users, who might only access the internet sporadically or for specific, limited purposes. This category includes a diverse demographic, encompassing various age groups, educational backgrounds, and socio-economic statuses. Regular internet use is often higher among younger people, professionals, and those living in urban areas, reflecting greater access to digital infrastructure and familiarity with technology. However, with the increasing penetration of mobile internet and more widespread digital literacy, regular internet usage is becoming more common across all segments of the population. The significance of being a regular internet user extends beyond mere access. It implies a level of digital literacy and competence in navigating the online world. Regular users are likely to be familiar with multiple digital platforms, understand the basics of online safety, and be capable of leveraging the internet for personal, professional, and social benefits (Kung and Steptoe, 2023; Villanti et al., 2017; Fox et al., 2016; Greenberg-Worisek et al., 2019). | ISTAT-BES |
| Availability of at least one computer and Internet connection in the family | AOC | Refers to the presence of both a computer and an active internet connection within a household, enabling family members to access digital resources, communicate online, and perform various tasks that require connectivity. This variable is a key indicator of digital inclusion, reflecting the household's ability to engage with the digital world. A computer, in this context, includes any desktop, laptop, or similar device capable of performing computing tasks, such as running software applications, accessing the internet, and storing data. The presence of at least one computer in the family suggests that household members have the tools necessary for tasks like online learning, remote work, research, and digital communication. An internet connection refers to the household's access to the global network, typically through broadband, fiber-optic, DSL, or mobile data services. The availability of an internet connection is crucial for enabling real-time communication, accessing online information, streaming content, and participating in the digital economy. It allows family members to connect with educational resources, social networks, work platforms, and government services, significantly enhancing their ability to participate in modern society. This variable is often used to assess digital equity and the digital divide. Families with access to a computer and the internet are generally better positioned to take | ISTAT-BES |

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| | | advantage of opportunities in education, employment, and social interaction. Conversely, the absence of these resources can limit access to critical information and opportunities, exacerbating social and economic inequalities (Gallardo, 2019; Meyer, 2016; Mhlanga and Dunga, 2023; de Araujo and Reinhard, 2019). | |

## 4. Methodology

In the following part the methodology applied to conduct the research is presented.

First, we considered a descriptive analysis of the comparative statics: it allows for evaluating the impact of exogenous changes on the behaviour of companies across different Italian regions. For instance, changes in government policies, such as the introduction of tax incentives for digitalization, can influence the percentage of companies adopting online sales. Comparative statistics enables the comparison of the situation before and after such policy implementations, providing a clear understanding of the effectiveness of these measures. The method is precious for comparing the situation across different regions, such as analysing how the adoption of online sales varies between northern and southern Italy in response to improvements in digital infrastructure or increased internet penetration. This comparison is essential for identifying regions that may require targeted interventions to close the digital divide and enhance the competitiveness of their businesses. Comparative statistics also allow predicting future trends by assessing the potential impact of anticipated exogenous changes. For example, suppose further increases in the adoption of digital technologies or shifts in consumer behaviour towards e-commerce are expected. In that case, this methodology can help anticipate how such changes might affect the distribution and behavior of companies with at least ten employees in different Italian regions. Additionally, comparative statics offers a relatively simple methodological approach compared to more complex models, such as dynamic simulations, making it accessible and practical for analysing scenarios where the effects of specific changes need to be understood without modelling the entire dynamic adjustment process of

companies. This approach provides valuable insights for strategic planning and policy formulation. Finally, comparative statistics focuses on market equilibrium, assessing how companies reach a new equilibrium after an exogenous change. In the case of companies with at least ten employees that engage in web sales, this approach helps to understand how changes in market conditions or public policies might influence the number of companies adopting e-commerce as a primary sales channel. In summary, descriptive comparative statics is a valuable method for examining how companies with at least 10 employees that engage in web sales to end customers adapt to external changes, facilitating the understanding of regional dynamics, the prediction of policy impacts, and the evaluation of future trend (Mensi et al., 2018; Pawlewicz et al., 2019; Silvestri et al., 2020; Christensen, 2019; Vergamini et al., 2019).

As a second step we performed a cluster analysis based on the K-Means algorithm to identify meaningful groups of observations in our data. K-Means is a non-supervised clustering algorithm that organizes data into homogeneous clusters based on similar characteristics (about the relevance of cluster analysis see for instance Magazzino et al. 2023 and Drago & Scozzari 2023). K-Means computes the centroid of the clusters and then assign every data point to its closest cluster. Computationally, k-Means is efficient, especially with few clusters. This will make the algorithm efficient for large datasets and thus applicable to extensive data problems, from customer segmentation in marketing to more complex ones like image compression and computational biology. Besides, k-Means is highly scalable. It may use parallel and distributed algorithms to treat massive datasets independently, which is handy when dealing with big data. It converges fast, returning results quickly—this can turn out vital in a scenario where timely results are needed. k-Means performs extraordinaire with continuous numerical data if the clustering is spherical/circular with equal-sized clusters. Results from k-Means are relatively easy to interpret since the centroids of clusters can be described by their average characteristics. Due to the versatility of the algorithm, k-Means finds applications in many practical fields: market segmentation, image compression, user behavior analysis, and computational biology. Though k-Means itself has certain disadvantages, like sensitivity to the initial values of the centroids or difficulty in choosing the correct number of clusters, all these can be improved by methods such as the Elbow method or Silhouette score to choose the correct value of k. The algorithm is run for regional aggregation within the framework of Italian businesses making web sales based on variables like the percentage of enterprises that make online sales, their digitalization, internet penetration, and other socio-economic measures. This results shows clusters of regions that share similar characteristics and hence allows. One of the methods used in deciding upon the number of clusters to be used in K-Means is known as the Elbow method (about clustering validation see also Drago et al. 2024 Magazzino et al. 2023). In the case of Italian firms, applying the

Elbow method will help draw out the number of regional groups that describe structural differences in online sales and optimize the model's ability to capture regional diversity. As an example, the Silhouette coefficient is a measure of how appropriate it is that data points are clustered concerning the clusters created, considering at the same time intra-cluster cohesion and inter-cluster separation. The higher the Silhouette value is, the more these regions are different between clusters, and there is little overlap among the groups. Using the Silhouette coefficient in the case of companies with web sales assures that with k-Means, the quality of the clusters obtained will at least have regions that belong to each cluster that are homogeneous but themselves well differentiated. k-Means, optimized with the Elbow method and validated with the Silhouette coefficient, will help gain more insight into regional differences. For example, it will individuate those regions while considering e-commerce adoption and compare them with regions from different clusters, underlining structural differences across Italian regions and showing which areas could most benefit from targeted interventions aimed at diffusing digitalization and e-commerce adoption. Finally, optimized and validated k-Means clustering can be very instrumental in strategic decision-making by policymakers or business managers. Knowing which regions cluster together based on shared characteristics allows for establishing zone-specific policies that are better attuned to local needs. Indeed, regions with a meagre rate of firms involved in e-commerce should require investments in digital infrastructure or specific training programs. In summary, applying k-Means clustering, optimized with the Elbow method and the Silhouette coefficient, to companies with at least ten employees who realize web sales to end customers in Italian regions provides a firm methodological framework. It offers knowledge about regional distribution and dis-homogeneities, helps identify groups that are homogeneous, and supports strategic decisions based on quantitative evidence (Saputra et al., 2020; Yuan & Yang, 2019; Syakur et al., 2018; Wijaya et al., 2023; Ashari et al., 2023).

The application of regression analysis with panel methods on the case of companies with at least ten employees having web sales to end customers in Italian regions has relevant methodological implications—it gives robust insights into the evolution of e-commerce across different regions, showing significant variations over time. The panel methods, in which observations are made over several periods on the same entities, allows the researcher to analyse both cross-sectional and time-series variations, thereby providing a more sophisticated understanding of the factors that help determine adopting web sales. In this way, panel regression can control unobserved heterogeneity and account for the inherent differences between regions that do not change over time, for example, cultural factors, historical economic development, or preferable baseline technological infrastructure. This is important in the Italian context, as regional disparities are substantial, and leaving out these fixed effects might bias the estimate. Moreover, panel methods can handle endogeneity with greater

ease in the presence of fixed or random effects models, which can potentially tackle the correlation of the regressors among error terms and, hence, be more reliable and consistent in estimating the effects of particular parameters. The scope of endogeneity can arise in binary applications with policy or regional characteristics, the impact of which, on the adoption of e-commerce, will arise due to simultaneity or omitted variable bias. On the other hand, panel regression permits the testing of dynamic impacts, capturing the changes in independent variables, for instance, improvements in digital infrastructure or changes in economic conditions, which affect the growth in web sales over time. This dynamic analysis is very much necessary for understanding the long-term impact of policy interventions or market developments on the digitalization of companies. In short, the use of methods on panel regressions in the present case allows one to give a composite, tight methodologically, with the analysis of the driving forces behind the adoption of web sales by companies located in the different regions of Italy, unravelling more the underlying temporal and regional dimensions of the phenomenon due to the structure of the data, addressing critical issues of econometric nature, such as unobserved heterogeneity and endogeneity (Bădîrcea et al., 2021; Gherghina et al., 2021; Billé et al., 2023; Pérez-Amaral et al., 2020; Romagnoli et al., 2022).

Finally, we performed a comparison a comparison between machine learning algorithms like Linear Regression, Decision Tree, Random Forest, SVM—Support Vector Machine—KNN—k-Nearest Neighbors—Gradient Boosting, AdaBoost, for prediction. Of course, there is some merit in all these algorithms; Linear Regression can model linear relationships easily, while Decision Trees and Random Forests can handle nonlinear relationships and interactions. SVM is robust in high-dimensional spaces, so KNN makes sense and is easy to interpret. Ensemble methods are a collection of improved predictive performance techniques that combine many weak learners, such as Gradient Boosting and AdaBoost. By comparing these algorithms, the researchers will know which model will have predictive accuracy, robustness, and generalizability in estimating the likelihood of firms adopting web sales based on regional characteristics such as digital infrastructure, economic development, market dynamics, etc. In this approach, it can also be found out which features or predictors are most important and significantly influence the adoption of e-commerce, which may vary across regions with different socio-economic contexts. It also portrays the comparison that will allow for the assessment of model interpretability relevant for translation into insights to policy and business leadership. In such contexts, a balanced model of optimal explainability-accuracy would be preferred if explainability had equal status to accuracy. Eventually, the capacity will be strengthened to make informed decisions on promotion strategies related to the adoption of digitalization and e-commerce while considering special needs and conditions in different regions. It equally makes a methodologically relevant comparison of machine-learning algorithms for prediction in a context that

provides an integrative framework about selecting the most suitable predictive model for assurance of the robustness and accuracy of predictions, which gives an in-depth understanding of what drives the adoption of e-commerce in Italian regions (Chaurasia and Pal, 2020; Singh, 2022; Nabipour et al., 2020; Bentéjac et al., 2021; Mustafa et al., 2023).

In conclusion, the research methodologies applied to analysing companies with at least ten employees engaging in web sales across Italian regions provide valuable insights into e-commerce adoption. Descriptive comparative statistics evaluate the impact of external changes, revealing regional disparities and the effectiveness of policies. Optimized with the Elbow method and Silhouette coefficient, the K-Means algorithm identifies homogeneous regional clusters, supporting targeted digitalization strategies. Regression analysis with panel methods deepens understanding of temporal and regional dynamics, addressing key econometric challenges. Lastly, comparing machine-learning algorithms ensures the selection of accurate and interpretable predictive models, aiding in informed decision-making and strategic planning to enhance digital competitiveness in Italy.

## 5. Rankings and Regional Disparities

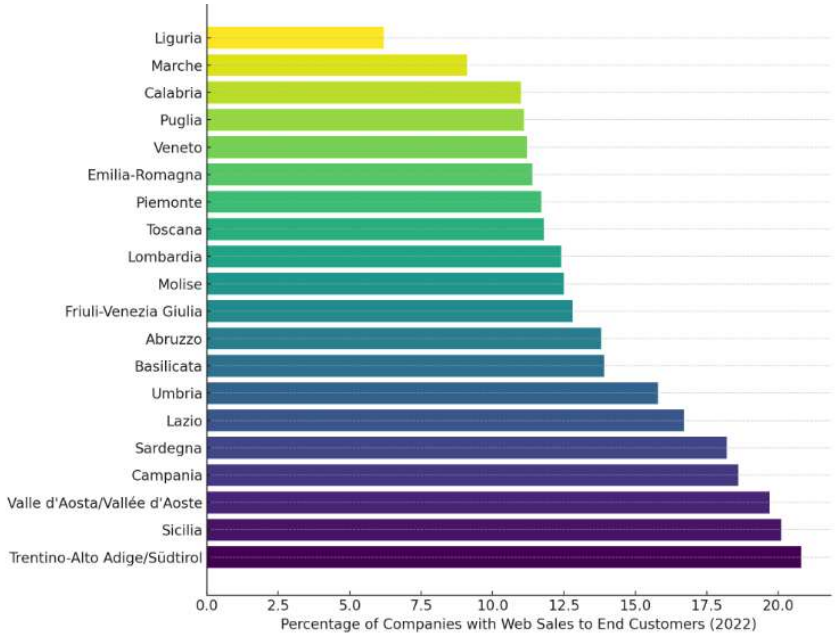
Istat counts companies with at least 10 employees with web sales and end customers. The variable is defined as the percentage of companies with at least 10 employees who sold via the web to end customers (B2C) during the previous year. From the same year of survey, the unit of analysis for which the estimates are provided is the enterprise, i.e. a statistical unit that can be made up of one or more legal units. The data refers to the Italian regions between 2013 and 2022[1] (De Fausti et al., 2019).

*Companies with at least 10 employees with web sales to end customers in 2022*. The analysis of data relating to companies with at least 10 employees carrying out web sales to end customers in 2022 reveals a varied adoption of e-commerce among the Italian regions, with percentages ranging from 6.2% to 20.8%. At the top of the list, we find Trentino-Alto Adige/Südtirol with 20.8%, closely followed by Sicily with 20.1% and Valle d'Aosta/Vallée d'Aoste with 19.7%. This data points to an interesting phenomenon: geographically and socioeconomically diverse regions rank at the top when it comes to e-commerce adoption, suggesting that the willingness to engage in online sales is not limited to traditionally more industrialized or affluent areas. Particularly notable is the case of Sicily, a region that, despite economic challenges, shows robust e-commerce penetration among local businesses. Likewise, the presence of Valle d'Aosta and Campania among the top positions dispels the myth that Northern Italy is significantly more advanced than the South in terms of business

[1] https://www.istat.it/it/archivio/282920

digitalisation. On the other hand, regions such as Lombardy and Emilia-Romagna, notoriously among Italy's economic engines, record relatively low percentages of businesses selling online, only 12.4% and 11.4% respectively. This could reflect a different composition of the business fabric, with a greater weight of sectors less inclined to online sales, or it could indicate areas of growth for e-commerce in these regions. The position of Liguria is surprising, in last place with 6.2%, a figure significantly lower than the other regions. This could suggest specific barriers to e-commerce adoption in this region, such as a lower propensity for digital innovation or logistical and infrastructure difficulties. In conclusion, these data highlight a map of Italian e-commerce that does not necessarily follow the traditional North-South economic divisions or expectations linked to the size and economic strength of the regions. Rather, they indicate an evolving landscape, where e-commerce emerges as a growth opportunity for businesses throughout the country, underlining the importance of targeted support strategies and investments in digitalisation for the regions that are lagging behind (Cirillo, et al., 2023; Soava et al., 2022; Calvosa, 2023).

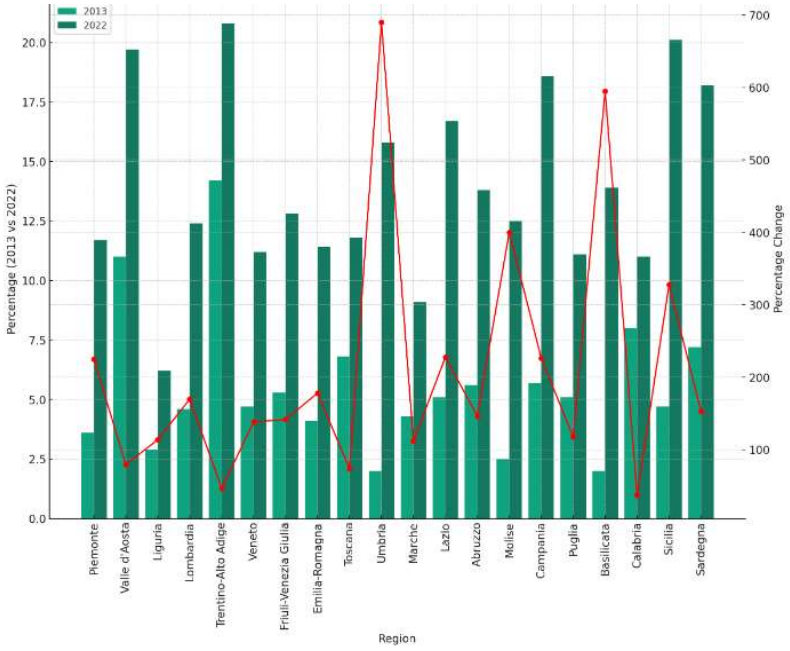
Figure 2. Percentage of companies with at least 10 employees that have web sales to end customers in Italy for 2022.




The analysis of data on Italian companies with at least 10 employees carrying out web sales to end customers between 2013 and 2022 highlights a significant growth trend of e-commerce. This growth is evidenced by both the absolute and percentage change in web sales, reflecting a digital transformation across different regions. In particular, regions such as Umbria and Basilicata show

notable increases, with percentage variations of 690% and 595%, respectively. This data suggests that even regions with a relatively low starting point in terms of online sales have embarked on exponential growth paths. On the other hand, regions with a more developed economy and a denser entrepreneurial fabric such as Lombardy and Emilia-Romagna also recorded significant increases, albeit starting from higher bases, with percentage variations of 169.56% and 178.04% respectively. Valle d'Aosta/Vallée d'Aoste, despite an absolute increase of 8.7 percentage points, shows a lower percentage variation (79.09%) compared to the others, suggesting that some smaller regions or with local specificities may have already had relatively high e-commerce penetration prior to the period considered. Trentino-Alto Adige/Südtirol and Calabria present more moderate increases, of 46.47% and 37.5%, respectively, perhaps indicating a more gradual growth or saturation in terms of adoption of e-commerce by businesses. Sicily, with a jump of 327.65%, and Sardinia, with 152.77%, highlight how the islands are also significantly embracing online sales, benefiting from the opportunities offered by e-commerce to overcome barriers geographical. These data indicate a substantial transformation in the way Italian companies approach the market, with an increasingly marked orientation towards digital. E-commerce emerges as a crucial commercial channel, capable of offering new business opportunities and reaching customers outside traditional boundaries. The widespread growth of e-commerce in Italy reflects not only the adaptation of businesses to new technologies but also a greater propensity of Italian consumers to purchase online, a phenomenon perhaps also accelerated by the circumstances imposed by the COVID-19 pandemic. This change poses new challenges and opportunities for companies, which must navigate in an increasingly digitalized and competitive environment, but also offers the exciting possibility of expanding their market and innovating their business models (Falk and Hagsten, 2015; Liuzzo et al., 2019).

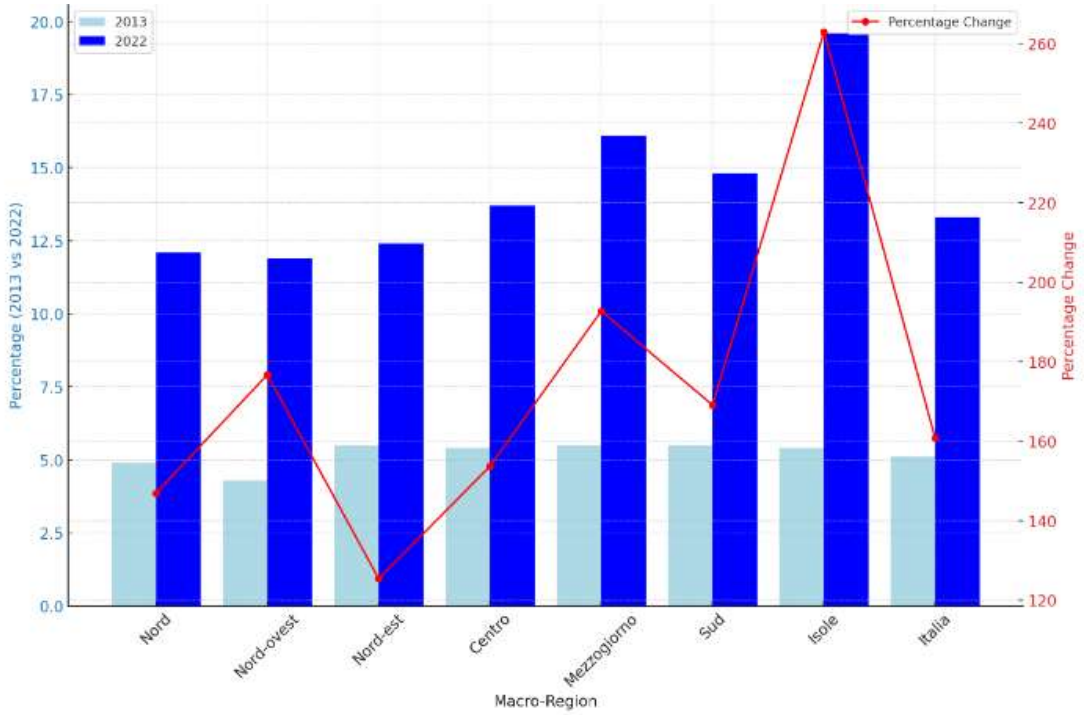
Figure 3. Companies with at least ten employees with web sales to end customers in the Italian regions between 2013 and 2022.




The analysis of data relating to Italian companies with at least 10 employees who have recorded web sales to end customers shows significant growth in the period considered, from 2013 to 2022. In particular, a general trend of increasing adoption of the electronic commerce between businesses, with absolute and percentage variations reflecting a significant change in sales behaviour. The Islands region stands out for having recorded the highest percentage change, with an increase of 262.96%, going from 5.4% to 19.6%. This suggests not only rapid adoption of online sales in this area, but also untapped potential at the start of the reporting period. On the contrary, the North-East, despite having shown a solid increase, records the lowest percentage growth among the macro-regions, with an increase of "only" 125.45%, which in any case almost doubles the share of companies engaged in web sales to 2022. The macro-region of the South, including the South and the Islands, also shows notable growth, underlining a dynamic of rapid expansion of online sales which exceeds the national average, with the South reaching an increase of 192.73% and the South with an increase of 169.09%. These data highlight how regions traditionally considered less dynamic from an economic point of view are rapidly catching up in e-commerce, potentially reducing the development gap with the Northern regions. The North, divided into North-West and North-East, although starting from a lower percentage base than other regions in 2013, saw a strong increase in online sales, with the North-West showing the highest absolute variation (7.6%) and a percentage growth of 176.74%, underlining the solidity and resilience of the entrepreneurial fabric of this area. The Central region, which includes the capital and other vital areas of the Italian economy, is no exception, with an increase of 8.3% in

absolute terms and a percentage growth of 153.70%, which testifies to a broad adoption of online sales. In conclusion, these data reflect a profound transformation in the way Italian companies approach the market, with an increasingly marked inclination towards digital. This trend, highlighted by the growth of online sales in all Italian macro-regions, not only testifies to the adaptability and innovativeness of the country's entrepreneurial fabric, but also opens up reflections on future strategies of economic development, digitalisation and territorial inclusion. The implications of this e-commerce growth for economic development and digitalization are significant and warrant further exploration (Reggi et al., 2014; Aronica et al., 2021; Alimonti et al., 2020; Jaganjac et al. 2020).

Figure 4. Changes in companies with more than ten employees selling online in the Italian macro-regions.



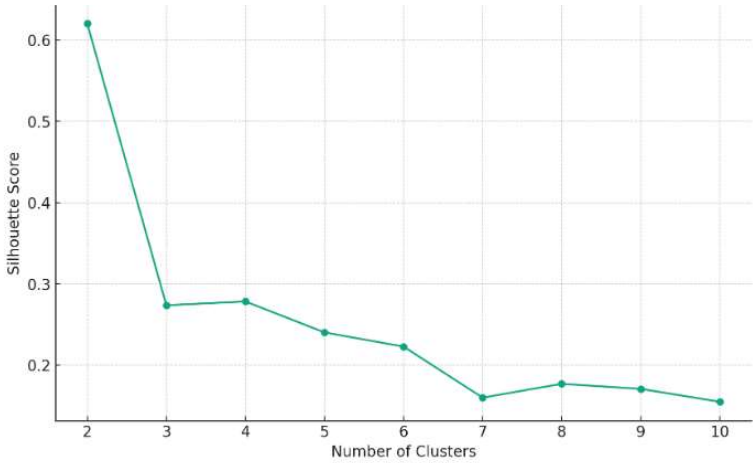

The value of companies with at least 10 employees with web sales to end customers grew by 154.84% on average between 2013 and 2022 in the Italian regions. Training and consultancy are crucial in helping SMEs understand the benefits of selling online and develop effective digital marketing strategies. Investing in developing digital infrastructure, especially in less developed regions, is also essential to ensure that all businesses have access to fast and reliable internet connections. Facilitated access to credit would allow small and medium-sized businesses to invest in digital technologies. At the same time, public-private partnerships could promote the creation of e-commerce platforms beneficial to small regional businesses. Simplifying e-commerce regulations, including cross-border sales, and supporting the digitalization of production processes would improve the efficiency and

competitiveness of Italian businesses. Finally, territorial promotion through digital marketing could enhance local specificities and attract new customers. By implementing these policies, a favourable environment would be created that would stimulate Italian businesses to expand online sales, supporting economic growth at both a regional and national level (Vargas-Hernández, 2015; Gao et al., 2023; Kuester et al., 2018; Elia et al., 2021).

## 6. Cluster analysis with k-Means Algorithm with a Comparison between the Optimization with the Silhouette Coefficient and the Elbow Method

The Silhouette score, a measure of how similar an object is to its cluster compared to others, plays a pivotal role in determining the optimal number of clusters. A higher Silhouette score indicates that the object is well-matched to its cluster and poorly matched to neighbouring clusters, suggesting an exemplary clustering configuration. The plot (See Figure 4) shows how the Silhouette score varies with the number of clusters. Based on the highest Silhouette score, the optimal number of clusters is 2. This suggests that when we segment the dataset into 2 clusters, we achieve the best trade-off between having the data points well-matched to their own cluster and poorly matched to neighbouring clusters, thus providing a meaningful grouping (Nitya Sai et al., 2017; Shahapure & Nicholas, 2020; Hou, 2019; Dinh et al., 2019; Patel et al., 2022).

Figure 5. Relationship between the Silhouette coefficient and the number of clusters.

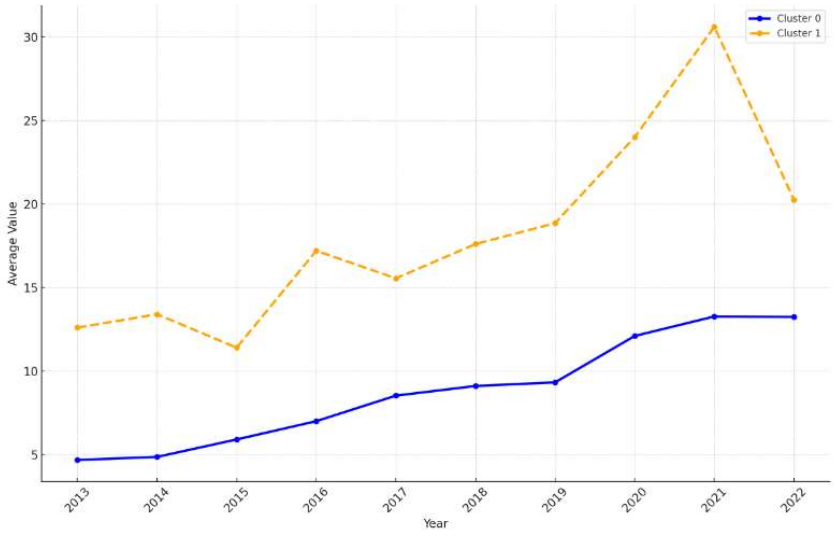



The final k-means clustering with 2 clusters resulted in the following cluster assignments for each region:

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

Cluster 0 comprises regions from various parts of Italy, including major economic centers like Lombardy and emerging regions like Calabria and Sicilia. Including these diverse regions in a single cluster suggests that, despite geographical and possibly sectoral differences, there's a commonality in how these regions' SMEs engage in web sales to end customers. It could indicate that businesses in these regions, regardless of their specific local economic context, have similarly embraced online sales channels to reach end customers, potentially driven by broader national or global trends in consumer behaviour and digital transformation. In contrast, cluster 1, exclusively containing Valle d'Aosta and Trentino-Alto Adige, reflects a distinct scenario. These are regions known for their geographic and economic features, including significant tourism sectors, higher levels of local autonomy, and possibly unique consumer behaviors. Their separation into a distinct cluster underscores their approach to web sales to end customers, which could be due to several factors, such as a different mix of products and services offered online, marketing strategies tailored to their specific tourist or local markets, or higher levels of digital maturity and innovation in e-commerce practices ( See Figure 6) (Mulyani et al., 2023; Zhou, 2021; Belkadi et al., 2021).

Figure 6. Average value of the clusters in the observation period. It is possible to verify that cluster 0 tends to be structurally dominant compared to cluster 1 in the sense of the observed variable.

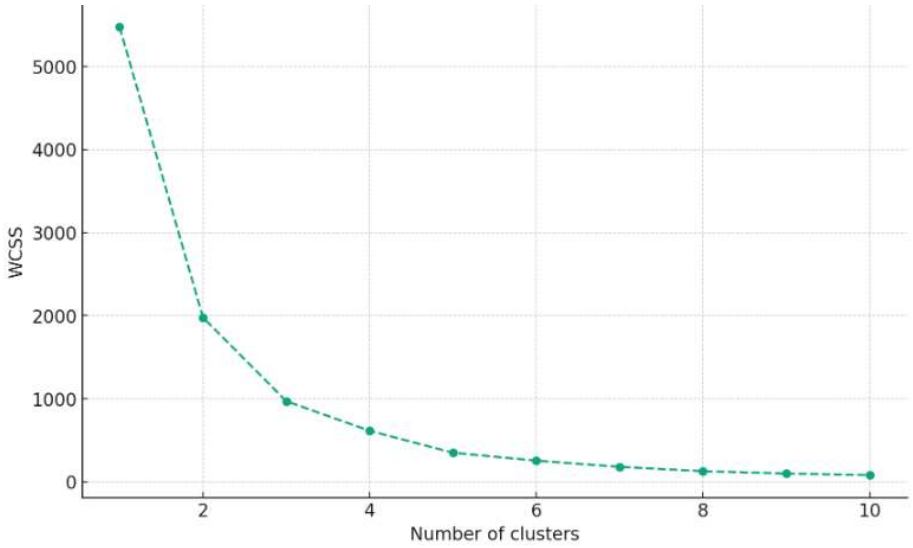



The clustering underscores the variability in e-commerce adoption and practices among SMEs across Italy. While Cluster 0 regions may represent a national trend of embracing digital sales channels, the

distinct nature of Cluster 1 suggests regional nuances, particularly in areas with unique economic structures or consumer markets.

The Elbow Method is used to determine the optimal number of clusters for a k-means clustering algorithm. The graph, with the number of clusters on the x-axis and the within-cluster sum of squares on the y-axis, helps us identify the 'Elbow' point (See Figure 7). This point signifies a slowdown in the rate of WCSS's decrease, indicating that adding more clusters does not improve model performance. According to the Elbow method, the optimal number of clusters is 3 (Nainggolan et al., 2019; Humaira and Rasyidah, 2020).

Figure 7. Elbow Method. The optimal number of clusters is k=3.




Our decision to employ a clustering method with k=3 is of significant importance. This method has provided us with the following cluster characteristics:

- Cluster 0: Toscana, Lazio, Campania, Calabria, Sicilia, Sardegna. This cluster includes regions with significant growth or high percentages in web sales to end customers. The presence of Toscana and Lazio, regions known for their robust economies and innovation hubs, suggests a mature digital commerce environment. Campania, Calabria, Sicilia, and Sardegna showing up in this cluster may indicate a strong growth in digital commerce, possibly driven by the necessity to reach broader markets beyond local and tourist-based economies. These regions, combining both central and southern parts of Italy, highlight a successful expansion of web sales activities, possibly supported by improvements in digital

infrastructure and a robust entrepreneurial spirit focused on leveraging online sales channels (Algieri & Álvarez, 2023; Carmela, 2020).

- Cluster 1: Piemonte, Liguria, Lombardia, Veneto, Friuli-Venezia Giulia, Emilia-Romagna, Umbria, Marche, Abruzzo, Molise, Puglia, Basilicata. This cluster is the largest and includes a mix of regions from the north, center, and south of Italy. The presence of regions such as Piemonte and Veneto, known for their industrial output and export activities, suggests that companies in these areas have a consistent but more moderate growth in web sales. This could be due to various factors, including already established sales channels, the nature of goods and services offered, or the gradual adoption of e-commerce practices. The diversity of this cluster also reflects the widespread nature of e-commerce adoption across different types of regional economies, from the highly industrialized north to the more agricultural and traditionally less industrialized regions like Puglia and Basilicata (Brunetta et al., 2007; Podestà, 2017; Ruggeri et al., 2023).
- Cluster 2: Valle d'Aosta, Trentino-Alto Adige. This cluster stands out due to its smaller size and the specific characteristics of Valle d'Aosta and Trentino-Alto Adige. These regions are known for their high quality of life, significant tourist appeal, and strong local economies that may not rely heavily on web sales. The clustering here might indicate a lower growth rate in web sales to end customers, potentially because of a strong focus on tourism and local/in-person sales channels or possibly due to the types of products and services that predominate these economies (e.g., artisanal, agricultural products, and tourism services). Despite this, the presence in this cluster does not necessarily mean these regions are lagging in digital adoption but instead suggests a different economic structure where web sales have not been the primary focus or have grown at a different pace (Franch et al., 2017; Orusa & Borgogno Mondino, 2021; Fazari & Musolino, 2023).

This ordering reveals that, on average, Cluster 2, despite being the smallest cluster, has the highest web sales percentages. However, only some have significantly embraced web sales for end customers. Cluster 0 comes in second, indicating robust growth and adoption of e-commerce practices. Cluster 1, the largest cluster, has the lowest average, which might reflect a more gradual and diverse integration of e-commerce across various types of economies within these regions. Considering the average value of the clusters, it is possible to verify the following ordering: Cluster 2>Cluster 0>Cluster 1. These results may appear paradoxical; in fact, many regions that present very high levels of digitalization and innovation are part of Cluster 1 or the cluster that presents the lowest levels in terms of the orientation of small and medium-sized enterprises towards online sales. The reference is to Piedmont, Lombardy, Veneto, and Emilia Romagna, which are within the same cluster as Molise,

Puglia, and Basilicata. This result appears paradoxical. However, it can be understood if we consider that the economy of Northern Italy is made up of small and medium-sized enterprises that operate in the B2B supply chain both in the service sector and in the manufacturing sector (Patti & Schifilliti, 2023; Leydesdorff & Leydesdorff, 2021).

Choosing the optimal number of clusters is a crucial step in our analysis. In the previous analysis, we presented the maximized clustering through two methods: the Silhouette coefficient and the Elbow method. The results put forward by the two methods are very different from each other. In the case of the Silhouette coefficient, 2 was the optimal value for k. For the Elbow method, the optimum value is set at k = 3. After careful consideration of the composition of the clusters, we have chosen to opt for k=3 as suggested by the Elbow method. This decision is based on the fact that with k=2, one condition is established: the dominant cluster is made up exclusively by Valle d'Aosta and Trentino Alto Adige, while the less performing cluster includes the remaining 18 Italian regions. This unequal and radical distribution does not allow for the possibility of grasping the complexity and heterogeneity of the Italian regions. In view of the comparison between the results coming from the Silhouette coefficient that indicated k=2 as the optimal number of clusters and the Elbow method suggesting k=3, we have chosen the latter value. This value of k allows more representativeness of the complexity of digitalization levels within the Italian regions. In summary, the k = 3 value has been chosen as it provides a better representation of the heterogeneity among the Italian regions in terms of values of SMEs' access to the Internet.

## 7. The Econometric Model

The following econometric model estimates the value of companies with at least 10 employees that make web sales to end customers in Italian regions. The retrieval of data for analysis was based on the ISTAT-BES database. The data ranged from the year 2004 up to 2022, covering 20 Italian regions. The analysis was done using the panel data technique.

The estimated equation is shown below:

$$\boldsymbol{SME_{it} = \alpha + \beta_1 (CCE)_{it} + \beta_2 (RIU)_{it} + \beta_3 (AOC)}$$

Where i=20 and t=[2004;2022]. Results are showed in the Table 2.

Table 2. Results of the panel data estimations.

| | Fixed-effects, using 380 observations | 1-step dynamic panel, using 340 observations | WLS, using 380 observations | Random-effects (GLS), using 380 observations |
|---|---|---|---|---|

| | Coefficient | Std. Error | t-ratio | Coefficient | Std. Error | z | Coefficient | Std. Error | t-ratio | Coefficient | Std. Error | t-ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Const | −1.42015** | 0.604930 | −2.348 | | | | −0.475347 | 0.473 | −1.005 | −1.37478* | 0.72770 | −1.8 |
| CCE | 0.508037*** | 0.184417 | 2.755 | 0.461*** | 0.143 | 0.7755 | 0.425236*** | 0.137181 | 3.100 | 0.505852*** | 0.18252 | 2.771 |
| RIU | 0.579465*** | 0.0468708 | 12.36 | 0.365*** | 0.072 | 3.208 | 0.534744*** | 0.0343246 | 15.58 | 0.578821*** | 0.04611 | 12.55 |
| AOC | −0.422816*** | 0.0472772 | −8.943 | −0.196*** | 0.066 | 5.042 | −0.405610*** | 0.0344756 | −11.77 | −0.423056*** | 0.04646 | −9.1 |
| SME(-1) | | | | 0.0806305 | 0.066 | −2.947 | | 0.473178 | | | | |
| Statistics | Mean dependent var 5.123684<br>Sum squared resid 3527.740<br>LSDV R-squared 0.755913<br>LSDV F(22, 357) 50.25437<br>Log-likelihood −962.5625<br>Schwarz criterion 2061.749<br>rho 0.393438<br>S.D. dependent var 6.175282<br>S.E. of regression 3.143505<br>Within R-squared 0.736518<br>P-value(F) 3.61e-95<br>Akaike criterion 1971.125<br>Hannan-Quinn 2007.085<br>Durbin-Watson 1.167506 | | | Sum squared resid 3961.37<br>S.E. of regression 2.413618 | | | Sum squared resid 355.2174<br>R-squared 0.770023<br>F(3, 376) 419.6492<br>Log-likelihood −526.3828<br>Schwarz criterion 1076.526<br>S.E. of regression 0.971971<br>Adjusted R-squared 0.768188<br>P-value(F) 1.4e-119<br>Akaike criterion 1060.766<br>Hannan-Quinn 1067.020<br>Mean dependent var 5.123684<br>Sum squared resid 4870.429<br>S.D. dependent var 6.175282<br>S.E. of regression 3.599065 | | | Mean dependent var 5.123684<br>Sum squared resid 4707.243<br>Log-likelihood −1017.36<br>Schwarz criterion 2058.495<br>rho 0.393438<br>S.D. dependent var 6.175282<br>S.E. of regression 3.533561<br>Akaike criterion 2042.734<br>Hannan-Quinn 2048.988<br>Durbin-Watson 1.167506 | | |

| | | | | |
|---|---|---|---|---|
| Tests | Joint test on named regressors -<br>Test statistic: F(3, 357) = 332.644<br>with p-value = P(F(3, 357) > 332.644) = 5.21481e-103<br><br>Test for differing group intercepts -<br>Null hypothesis: The groups have a common intercept<br>Test statistic: F(19, 357) = 6.25462<br>with p-value = P(F(19, 357) > 6.25462) = 6.72601e-14 | Number of instruments = 39<br>Test for AR(1) errors: z = -3.20667 [0.0013]<br>Test for AR(2) errors: z = -0.52505 [0.5995]<br>Sargan over-identification test: Chi-square(35) = 131.363 [0.0000]<br>Wald (joint) test: Chi-square(4) = 161.717 [0.0000] | | 'Between' variance = 3.27221<br>'Within' variance = 9.28353<br>theta used for quasi-demeaning = 0.639555<br>Joint test on named regressors -<br>Asymptotic test statistic: Chi-square(3) = 1005.71<br>with p-value = 1.03698e-217<br><br>Breusch-Pagan test -<br>Null hypothesis: Variance of the unit-specific error = 0<br>Asymptotic test statistic: Chi-square(1) = 145.951<br>with p-value = 1.33042e-33<br><br>Hausman test -<br>Null hypothesis: GLS estimates are consistent<br>Asymptotic test statistic: Chi-square(3) = 3.23132<br>with p-value = 0.357316 |

*Relationship between SME and CCE.* The relation that exists between e-commerce and the development of Italy's cultural and creative industries is not simply superficial but is one showing that there is a sea change in economic and cultural terms. E-commerce has helped spur a renaissance in the cultural and creative sphere. That fact is less an accident than a signal of how digital platforms have democratized the distribution of cultural goods and services, breaking down the traditional barriers to entry for both creators and consumers. Companies in this digital era are no longer bound by rigid geography; rather, they enable Italian cultural products-art, music, literature, fashion-to reach their markets around the world. It is crucial-to the economic vitality of those sectors, as well as to the cultural exchange and appreciation that such global reach fosters. Beyond that, the digital platform serves moreover as a feedback loop: the popularity and consumption of cultural products can directly be measured and replied to, which enables creators to adapt and innovate in ways unimaginable before. This, therefore, digital empowerment has caused a huge cultural shift in these regions that

boast of good e-commerce. It increases the value given to the creative professions, hence making them more viable and respectable. In return, this invites more vibrancy in the cultural ecosystem, discharging talents with investments. Benefits are aplenty, from job creation both in the digital and creative industry to a rise in tourism flows as wider global audiences become increasingly interested in the rich cultural heritage Italy has put on display online. However, it is equally a positive cycle that brings challenges-whether ensuring that all creatives have equal access to digital tools and platforms or authenticity and quality of cultural products in the face of commercial pressures. While the relationship between digital commerce and cultural proliferation is overwhelmingly positive, it ushers in this wide array of benefits and thus requires careful stewardship in order to sustain further growth and make sure that it actually benefits a broad spectrum of society. The burgeoning relationship between digital commerce and cultural industries in Italy represents one potentiality of technology in increasing cultural engagement as well as economic opportunity. It thereby speaks volumes about the power of the digital age to change traditional industries and cultural paradigms toward a new era of economic development that is inclusive, dynamic, and culturally enriched (See Figure 9) (Burlina et al., 2023; Lazzeretti et al., 2017; Natale and Piccininno, 2015; Leung and Law, 2017; Imperiale et al., 2021).

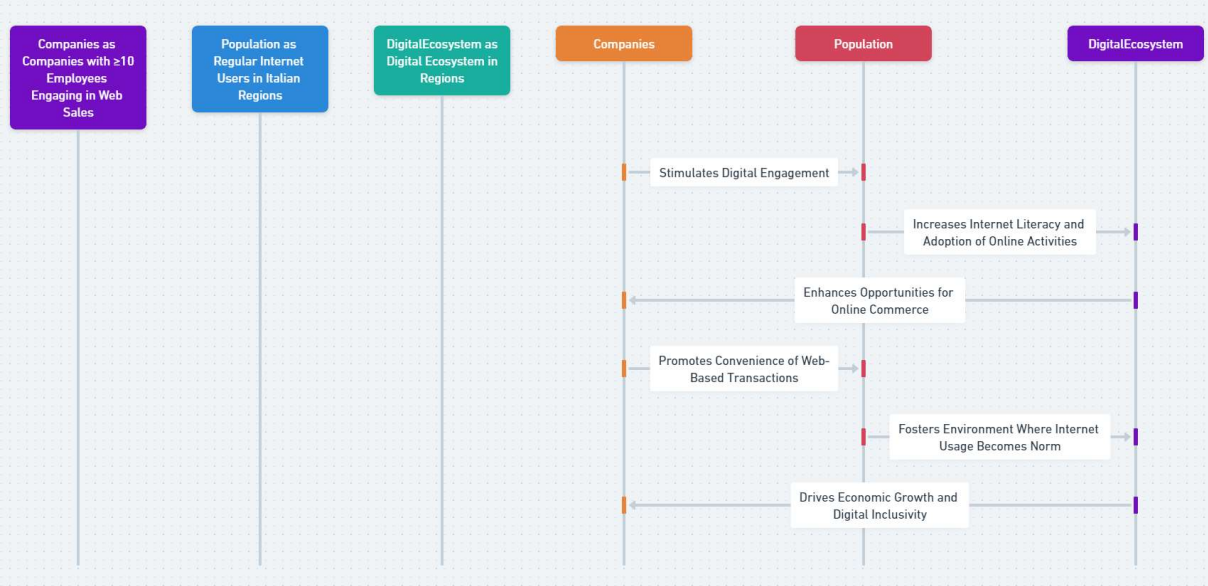
Figure 9. The positive relationship between SME e CCE.


*The relationship between SME and RIU.* The positive relationship between the digitally ready firms and the diffusion of internet use among the population in Italian regions is mutually beneficial and acts as the fulcrum of socioeconomic development. This interplay between digital literacy, economic diversification, and social inclusion raises their combined effect towards a connected and resilient society. First and foremost, companies adept at selling through digital platforms increase people's

digital literacy. Since these companies are coming up with new services on online platforms, they unknowingly become a driving force pushing people toward learning and acquiring skills to serve themselves in the best possible way using digital space. This pedagogic dynamic is critical, especially in areas with limited access to digital education resources, therefore democratizing digital knowledge through hands-on everyday interactions. The relationship also unleashes economic diversification. When areas become more digitally integrated, new niches and markets open up and present opportunities for businesspeople to innovate. The digital economy is diverse in e-commerce, software development, digital marketing, and online entertainment. Such diversification strengthens the economic fabric of these regions and makes them more adaptable to global economic shifts and technological advancement. Moreover, integrating digital commerce significantly advances social inclusion by providing an impetus to regular internet use among different demographic groups, regardless of age, socioeconomic status, or geographical location, into the digital economy. This spans from simply accessing digital services and products to remote working and education opportunities. In effect, a critical concern for many regions, the digital divide begins to narrow, allowing for a more inclusive society where access to information, opportunities, and connectivity is not a preserve of the few but is the norm. Additionally, one must not forget about the environmental benefits of digital commerce. By introducing online transactions and operations, carbon footprints can be lessened by diminishing the demand for physical structure, hence fashioning a more sustainable approach toward business and consumer behavior. To this end, such environmental consciousness would meet the rising global demand for eco-friendly practices, thus adding to the reputation of Italian regions as being forward-looking and responsible in the face of global challenges. In other words, the dynamic interaction between firms dealing with web sales and the diffusion of regular Internet users produces a comprehensive ecosystem that will benefit the economy of Italian regions. In such a virtuous circle of digital engagement, underpinned by inclusivity and sustainability, is situated the potential for transformative change which digital commerce might hold towards

resilient and progressive societies (See Figure 10) (Iammarino et al., 2015; Ndou, 2023; Gutierrez-Angel, N. et al., 2022; Parianom et al., 2022; Wang et al., 2022; Pitaloka et al., 2023).

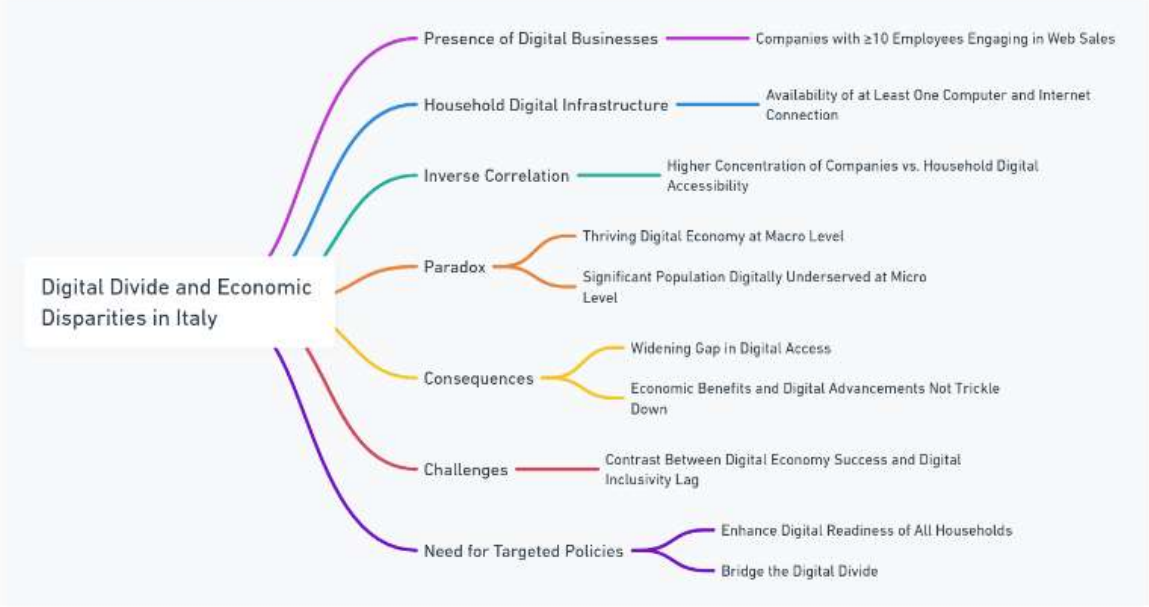
Figure 10. The positive relationship between SME and RIU.




*The relationship between SME and AOC.* The study of the paradoxical relation between the rise in digital-commerce companies with hooked employees on one side and, on the other, heterogeneous household digital infrastructure across Italian regions speaks to deeper issues related to the digital divide and socioeconomic inequality. This inverse relation suggests that when some regions can play host to a very vibrant digital economy, signified by firms adept in web sales, this prosperity does not translate to improved digital access for all households. This discrepancy lays bare a stark digital divide wherein economic growth in the digital sector coexists with a lack of digital inclusivity at the level of individuals and families. This is not the paradox of technological diffusion but one of more profound economic inequality. For example, communities with high shares of digital-commerce firms tend to treat these companies as drivers of future economic and innovative growth. Still, many of the advantages gained from such digital economies, either tech job creation or overall regional GDP growth, are likely to elude most residents, particularly those who live at lower socioeconomic levels. The assumption that corporate success in the digital realm directly leads to large-scale digital empowerment is flawed. On the contrary, increasing digital businesses may further enhance existing inequalities and thus inadvertently leave behind those without the wherewithal to access or use digital technologies effectively. The scenario brings forth a subtle layer of socioeconomic stratification

wherein this success story of the digital economy covers up the reality of people it fails to reach. That digital poor—be it lacking a computer or having an inadequate internet connection—widens the gap not only in digital but also in access to opportunities the digital world brings in terms of education, telework, and online services. The situation is of particular concern since the world is becoming increasingly digitized, making digital access not a luxury but a staple of modern life. Meeting such a challenge requires well-directed interventions beyond the impetus of pure market-driven dynamics in this digital commerce variant. It calls for concerted efforts by government, industry, and community stakeholders to ensure that digital progress is oriented toward inclusive growth. Subsidizing access to the internet, providing digital literacy programs, and ensuring access to affordable digital devices available for underprivileged families could go a long way in bridging the gap between these two extremes. In addition, gap-reducing policies could further promote increased corporate social responsibility investment by digital-commerce companies in community digital infrastructure. Moreover, this complex interplay of success in digital commerce and household digital access underscores how holistic approaches toward economic development—that is, being inclusive of digital inclusivity—must be ensured (See Figure 11) (Lucendo-Monedero et al., 2019; Di Pietro, 2021, van Kessel et al., 2022).

Figure 11. The negative relationship between SME and AOC.




## 8. Machine Learning Algorithms for Prediction

Table 3 compares machine learning algorithms in forecasting the value of SMEs having web sales to end customers in the Italian regions. The prediction will be carried out through the described machine learning algorithms. It may help to understand the possible trajectories of the Italian regions for the level of application of e-commerce in SMEs. The algorithms are tested regarding their possibility to maximize the R-squared and minimize the statistical errors.

Table 3. Statistical performance of machine learning algorithms used for prediction.

| Model | R-Squared | MAE | MSE | RMSE |
|---|---|---|---|---|
| Linear Regression | 0.291 | 1.35 | 2.558 | 1.599 |
| Decision Tree | 0.982 | 0.250 | 0.065 | 0.255 |
| Random Forest | 0.767 | 0.884 | 0.840 | 0.917 |
| SVM (Support Vector Machine) | 0.436 | 1.200 | 2.037 | 1.427 |
| KNN (k-Nearest Neighbors) | 0.429 | 1.270 | 2.062 | 1.436 |
| Gradient Boosting | 0.982 | 0.250 | 0.065 | 0.255 |
| AdaBoost | 0.982 | 0.250 | 0.065 | 0.255 |

Given these metrics, the Decision Tree, Gradient Boosting, and AdaBoost models stand out with an R-squared value of 0.982, which indicates that these models can explain 98.2% of the variance in the dependent variable. They also have the lowest error rates across MAE, MSE, and RMSE, making them the most accurate models among those listed. However, the choice between these three might depend on additional considerations such as:

- Interpretability: Decision Trees are typically easier to interpret and visualize compared to Gradient Boosting and AdaBoost;
- Computation Time and Complexity: Gradient Boosting and AdaBoost may require more computational resources and time to train than a simple Decision Tree, especially with large datasets;
- Tendency to Overfit: Gradient Boosting and AdaBoost might have a higher tendency to overfit, especially with noisy data, compared to Decision Trees which can be pruned to reduce overfitting.

If accuracy were the sole concern, either Gradient Boosting or AdaBoost would be recommended due to their high R-Squared value and low error metrics, suggesting they are both highly predictive and precise (Mohapatra et al., 2022; Bentéjac et al., 2021; Kadiyala and Kumar, 2018). When choosing

among Decision Tree, Gradient Boosting, and AdaBoost based on their performance metrics, which are identical in this case (R-squared: 0.982, MAE: 0.250, MSE: 0.065, RMSE: 0.255), the decision comes down to other factors such as model complexity, interpretability, and how they handle overfitting and bias-variance trade-offs. The main characteristics of these three algorithms are indicated as follows:

- Decision Trees are highly interpretable, easy to visualize, and simple to understand. They are useful for capturing linear and non-linear relationships but can easily overfit, especially with complex datasets;
- Gradient Boosting is a powerful ensemble technique that builds one tree at a time, where each new tree helps to correct errors made by previously trained trees. Gradient Boosting has a high level of predictive accuracy but is more complex and less interpretable than a single Decision Tree. It tends to perform well on a wide range of problems, especially where the data complexity requires capturing intricate patterns. However, it can be prone to overfitting if not carefully tuned and can be computationally intensive to train;
- AdaBoost starts by fitting a simple model e.g., a Decision Tree to the data and then fits additional copies of the model to the same dataset but where the weights of incorrectly classified instances are adjusted such that subsequent models focus more on difficult cases. AdaBoost is less prone to overfitting compared to Gradient Boosting and can be more robust with noisy data. However, like Gradient Boosting, its interpretability is lower than a single Decision Tree, and its performance heavily depends on the data and the complexity of the base estimator.

A Decision Tree shall be the model of choice if interpretability and simplicity are to be considered first, using straightforward datasets. Gradient Boosting stands out as the best option in conditions where predictive accuracy is the most important aspect, especially for complex datasets with complicated patterns that are not captured by a simple model. AdaBoost is a great practical trade-off between accuracy and overfitting, especially when the data is noisy or one is concerned about the sensitivity of the model against outliers. It can also be very easily adapted to different problems and is slightly easier to tune than Gradient Boosting. Given the equal performance measures, Gradient Boosting might be preferred when the highest predictive power is not only desired, but also sufficient resources and effort can be afforded for the proper tuning and validation of this type of model in order to manage overfitting (Park & Ho, 2019; Nagassou et al., 2023).

The predictions obtained by applying the Gradient Boosting algorithm are shown in Table 4.

Table 4. Predictions with Gradient Boosting Algorithm

| Region | 2022 | 2023 Prediction | Abs Var | % Var | Region | 2022 | 2023 Prediction | Abs Var | % Var |
|---|---|---|---|---|---|---|---|---|---|
| Piemonte | 11.7 | 11.70 | -0.0001 | -0.0011% | Marche | 9.1 | 9.10 | +0.0024 | +0.0261% |
| Valle d'Aosta | 19.7 | 19.70 | -0.0004 | -0.0022% | Lazio | 16.7 | 16.70 | -0.0003 | -0.0019% |
| Liguria | 6.2 | 6.21 | +0.0102 | +0.1649% | Abruzzo | 13.8 | 13.80 | -0.0022 | -0.0163% |
| Lombardia | 12.4 | 12.40 | -0.0001 | -0.0006% | Molise | 12.5 | 12.50 | -0.0005 | -0.0042% |
| Trentino-Alto Adige | 20.8 | 20.80 | +0.0005 | +0.0022% | Campania | 18.6 | 18.60 | -0.0002 | -0.0012% |
| Veneto | 11.2 | 11.20 | -0.0001 | -0.0006% | Puglia | 11.1 | 11.10 | +0.0028 | +0.0248% |
| Friuli-Venezia Giulia | 12.8 | 12.80 | -0.0024 | -0.0191% | Basilicata | 13.9 | 13.89 | -0.0110 | -0.0789% |
| Emilia-Romagna | 11.4 | 11.40 | +0.0017 | +0.0151% | Calabria | 11.0 | 11.00 | +0.0031 | +0.0286% |
| Toscana | 11.8 | 11.80 | -0.00001 | -0.00006% | Sicilia | 20.1 | 20.10 | +0.0001 | +0.0006% |
| Umbria | 15.8 | 15.80 | -0.0016 | -0.0102% | Sardegna | 18.2 | 18.20 | -0.0006 | -0.0033% |

In this network of regional economies, various diversification patterns arise that, with the prospect of realizing growth opportunities, also offer considerable challenges. First, the regions of Liguria, Trentino-Alto Adige, Emilia-Romagna, Marche, Puglia, Calabria, and Sicilia, with positive web sales, exhibit favourable market conditions in which to pursue further growth by increasing market penetration. This positive momentum suggests opportunities for strategic investment and resource allocation in these regions, as businesses look to capitalize on the increasing digital economy and changing consumer preferences. Other regions were less promising, however, with flat or decreasing web sales. These regions included Friuli-Venezia Giulia, Umbria, Lazio, Abruzzo, Molise, and Basilicata, where negative trends point to a need for greater attention and strategic interventional programs. These are regions where consumer behaviour has become so ingrained, competition is very strong, or infrastructure is absent and revitalization or reinvigoration has been relatively hard to achieve. In the future, it will be of essence that businesses and policymakers alike understand the drivers underlying the changing dynamics as the pre-requisite to building resilience and stimulating economic vibrancy in all kinds of regions.

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## 9. Policy Implications

Adopting a complex set of economic policies at the regional level in Italy could significantly increase the number of SMEs engaging in web-based sales to private consumers. The following section outlines several economic policies that could effectively enhance the adoption of online sales services among small and medium-sized enterprises across the Italian regions.

*E-commerce Infrastructure Development.* Investment in the infrastructure that supports e-commerce has a broad scope, covering physical and non-physical aspects necessary for a thriving digital economy. High-speed internet access should be extended to more populations and regions to provide equal online access, thus overcoming the digital divide. It further includes fortifying the reliability and security of the payment system for online payments through fraud-proof secure payment gateways that are safe for user data, a basis for building consumer confidence in digital transactions. Also, the e-commerce platform developed should be easily usable. Such platforms should be accessible and intuitive to people of any age and level of training and provide access for people with disabilities to make digital commerce truly inclusive (Hassan et al., 2020; Kirchner & Schüßler, 2019; Huang et al., 2018).

*Financial Incentives and Tax Breaks.* Offers of financial incentives and tax breaks to firms that invest in e-commerce capability are strategies that, viewed through different lenses, aid in fostering digital economies. However, such expenses could be a write-off from government revenue as an investment in creating a low-entry barrier for SMEs to go online in their sales strategies. Lower corporate taxes for e-commerce revenues further encourage businesses to put priority and expand their online presence; it recognizes their effort in adapting digital marketplaces. In addition, grants for technology adoption level the playing field for smaller players who would otherwise find it hard to afford upfront costs relating to digital transformation. This will not only lead to increased economic growth by

expanding the digital ecosystem but also to increased innovation and competitiveness among businesses. Policy enablers can build a more dynamic, inclusive, and resilient economy where firms are incentivized for innovation, which in turn can lead the benefits from digital commerce to filter down into the broader segments of society, including the marginalized ones, via incentives in the adoption of e-commerce (Dinis et al., 2023; Avdeeva, 2021; He and Li, 2023).

*Access to Funding and Support.* Access to finance and support to businesses in creating an online presence needs to be afforded. It is possible for governments, together with financial institutions, to effectively lower financial barriers, usually limiting small and medium enterprises from investing many resources in the development of e-commerce, through the creation of committed funding programs and the provision of favourable loans targeted to the development of e-commerce. Such financial instruments provide the capital needed to jumpstart e-commerce ventures and an important signal that the entrepreneur is committed to business enterprises in the digital era. Finally, these financial incentives need to be linked to providing advice and technical help. This will ensure that businesses are financially resourced, well-informed, and technically prepared to step through the web of complexity in getting started and growing businesses online. This complete support system would help speed up the transformation of traditional businesses to new business models that are digitally enabled while at the same time being a fertile environment for the nurturing of innovation (Chen et al., 2021; Gong et al., 2020; Tang & Yang, 2020).

*Training and Skill Development.* There is a need to offer training programs and workshops to enhance relevant digital skills in e-commerce to improve businesses and the workforce toward prospering in the digital marketplace. Such training should project a reasonable share of topics on website development, digital marketing, and online sales management in a way that gives participants enough insight into the tools and strategies involved in digitally undertaking e-commerce. Such programs must be industry- and business-specific, with varying sizes, so whatever is taught remains relevant and solves sector-specific challenges while grasping opportunities. With a bias towards practical learning, participants can put into practice the gained skills and knowledge, thereby making swiftness in implementation a reality for e-commerce solutions in their operations. While this strategy improves the e-commerce readiness of the businesses themselves, it also enhances digital literacy among the workforce. By backing these training or skill development initiatives, governments and industry leaders would support a culture of continuous learning and adaptation in the fast-evolving digital economy (Arianti, 2023; Rasyidan & Fachira, 2023).

*Regional Collaboration and Networking.* Such collaboration and networking among businesses, industry associations, and local government agencies would facilitate knowledge sharing and the

adoption of best practices in e-commerce as a strategic approach to leveraging diverse skills toward propelling the digital economy forward. A regional e-commerce cluster or hub would establish a concentrated ecosystem where stakeholders can cooperate and exchange information easily. Such clusters act as incubation centers of innovation, where any business—irrespective of size—can share resources, insights, and technology jointly. The collaborative environment expedites the process of innovative practice in e-commerce adoption and fosters a culture of incessant improvement and adaptiveness toward emerging digital trends. These hubs can act as catalysts for regional economic development by attracting investment and talent and showcasing collective capabilities and success stories across the e-commerce sector. They provide a platform for government agencies to engage better with the business community in tailoring support services and regulatory frameworks that will provide an enabling environment for the growth of electronic commerce. Regional collaboration and networking can significantly lower these start-up barriers in the online markets and make the playing field even for smaller enterprises, thus allowing them to compete at a bigger scale (Ly and Lai, 2020; Georgescu et al., 2022; Frick, 2023; Kumar et al., 2022) .

*Promotion of Digital Literacy*. Spending on programs that would improve digital literacy, not just for businesses but even consumers, would also go a long way in creating an effective ecosystem for operating e-commerce. Businesses need to be enriched with the benefits they would reap from e-commerce: enlarged market access, cost reduction, and enhanced perspectives on customer needs. By providing resources that ease business into adoption—removing some of the traditional barriers to adoption, like those that are inherently technological, in security matters, and logistical—the policymakers and industry leaders can enhance the more robust demand for electronic products and services. The approach will lead not only to faster digitalization of traditional kinds of businesses but also to fostering a more digitally well-informed clientele. Informed consumers, showing the benefit and protection of e-commerce, are more likely to participate, therefore driving the demand upward through a positive cycle. Enhanced levels of digital literacy will eventually increase confidence in online platform use and further stimulate businesses towards innovation and improvement in the online sphere. In addition, these digital literacy efforts have helped to level the playing field for small and medium-sized enterprises with some of the more prominent players (Ollerenshaw et al., 2020; Steyn, 2019; Nazir & Roomi, 2020; D'Adamo et al., 2021).

*Streamlined Regulatory Environment.* There is an urgent need to streamline and make clear the regulatory framework of e-commerce, including online transactions, personal data protection, and consumer protection, to facilitate the growth of digital commerce. Spelling out the friendly, enabling regulatory environment eliminates some relevant entry barriers or the great multiplication of business

for those currently in operation and wishing to start or expand operations online. Eliminating unnecessary bureaucratic hurdles and creating a more predictable legal framework in the business sector will also create a better confidence scenario for planning and investment in e-commerce projects. This is especially important for small and medium-sized enterprises, often more burdened in complex regulatory settings. Clear rules—in both data protection and consumer rights—protect people and provide more confidence for consumers using online platforms. It becomes more probable that they will generate demand by engaging in e-commerce if consumers are assured of the robust protection of their data and their rights in digital transactions. So, simplifying regulations actually benefits businesses and the cleaner e-commerce environment in which trust, innovation, and access generate mutual benefit between enterprises and consumers. Such an environment would be conducive to investment, innovation, and growth in the digital economy, which is essential for building a robust e-commerce sector (Buana et al., 2023; Barkatullah, 2018; Chawla & Kumar, 2022).

*Innovative Contribution.* The analysis of the presence of firms using e-commerce technologies by Italian regions is very important because of the strong gap between the regions of Central-Northern Italy and those of Southern Italy. The economic gap that unification created in 1861, although having been the object of economic policies whose aim was its reduction, further increased the differences between the Italian regions. These differences became cultural as well and influenced the distribution of human capital at the regional level. Consequently, there are also regional disparities in the use of technologies, underlining the problem of some areas being able effectively to access and utilise new technologies such as in the case of online sales. Another important point is that the Italian case is by no means an anomaly and that every nation necessarily contains heterogeneity between its regions. Indeed, most countries contain regions that are falling behind compared with others. The Italian case can therefore serve as a model even for other countries with large regional differences in the capability of firms to employ new technologies.

Another innovative contribution consists in the fact that the analysis considers variables that are closely related with the dimension of technological innovation, human capital, and knowledge economy. In this line of thinking, a model is proposed that goes beyond the classic analyses based on per capita GDP or the degree of investment in research and development and technological

innovation. This way, one will be able to reach such a model that can be used to separate the impact of innovation orientation on the use of online sales tools by SMEs. Therefore, the determinants of technological innovation and human capital are particularly in congruity with this analysis, since the role of information technologies is linked to the population's capability to develop a dynamic and creative approach to the knowledge economy. This topic develops particular relevance, above all in relation to the current international scenario characterized by the competition between the United States and China from a technological point of view. This would mean that, within such a framework, relations of a metric type should be sought that can stimulate economic policies aimed at guiding SMEs toward the generalized use of new technologies. The article shows therefore a relevant innovative contribution because it has chosen the issue of regional disparity for analysis, which is becoming increasingly relevant in the current rediscovery of the geopolitical role of economic areas in the international context. Further innovative contribution consists in the analysis of determinants concerning human capital and knowledge capital that will enable SMEs to be more active in the experimentation of new technologies in business activities.

## 10. Conclusions

The article explores the substantial variations in e-commerce adoption across different regions of Italy, providing crucial insights into the digital transformation processes. It highlights the widening inequalities in e-commerce adoption, which need to be addressed for Italy to achieve a proper digital recovery. E-commerce among SMEs is identified as a key factor that could boost the digital economy at national level. The research underscores the significant regional disparities in e-commerce, a major driver of economic development. Using data from the ISTAT-BES database, it was found that regions such as Trentino-Alto Adige/Südtirol and Valle d'Aosta lead in e-commerce adoption. In contrast, economically richer regions like Lombardy and Emilia-Romagna perform poorly relatively. This counterintuitive finding challenges traditional assumptions that digitally advanced markets are only found in industrially developed regions, suggesting that factors like sectoral composition or regional policy support might be more influential. Clustering analysis, particularly the k-Means algorithm, provides further evidence of these differences. The optimal clustering reveals that regions can be grouped into three clusters based on e-commerce adoption metrics. The insights from the Elbow Method, which identified three optimal clusters, are particularly notable. The clustering highlights regions that are uniformly adopting e-commerce and suggests targeted policy interventions for lagging regions. Econometric analysis shows a positive correlation between e-commerce adoption

among SMEs, cultural and creative employment, and regular internet usage. This indicates that regions with a higher concentration of cultural and creative industries, typically innovative and tech-savvy, tend to have higher e-commerce adoption rates. This suggests that fostering cultural and creative sectors could be a strategic approach to broadly boosting e-commerce adoption. Conversely, a negative correlation with the availability of computers and internet connections in households suggests a potential disconnect between household digital infrastructure and SME e-commerce activities. This finding indicates that even regions with good household digital infrastructure do not necessarily have higher e-commerce adoption among SMEs, possibly due to factors like a lack of business support for digital transitions or the predominance of sectors less inclined to use online sales channels. The article provides actionable insights for policymakers, suggesting that hierarchical and tailored strategies might be appropriate, such as targeted subsidies for e-commerce adoption in lagging regions or improvements to digital infrastructure. Additionally, promoting cultural activities could serve as an indirect incentive for e-commerce uptake, especially in regions with lower levels of digital development. This study reinforces the importance of caution when creating digitization policies. While boosting households' digital infrastructure is essential, it does not take away the need for intervention on another front, which this study seeks to establish: a need to support SMEs directly via training, digital literacy programs, and business-oriented incentives focusing on promoting digitally enabled transactions. The fact that the Elbow Method suggests three clusters are ideal further evidences how nuanced and complex regional differences within Italy can be, highlighting the need for policies to focus more on a local level. Through these insights, Italy can more fully account for its region's unique priorities and possibilities when shaping digital strategies that foster more balanced growth across the country. This article offers a detailed analysis of e-commerce diffusion among Italian SMEs, focusing on the importance of territorial differences in Italy's digital economy. The research highlights the current level of e-commerce adoption and serves as a useful resource for predicting future trends while offering guidelines for shaping future policies. As Italy continues its digital transformation, narrowing the regional disparities will be essential to ensuring that all areas of the country can fully participate in and benefit from the new economy. Policymakers can use the findings of this study to implement strategies that promote digital growth and support prosperity across the country.

## 11. List of Abbreviations

| Variable | Acronym |
|---|---|
| Small and Medium Enterprises | SMEs |

| | |
|---|---|
| Weighted Least Squares | WLS |
| Artificial Intelligence | AI |
| Technology-Organization-Environment | TOE |
| Business to Business | B2B |
| Micro, Small and Medium Enterprises | MSME |
| Enterprise Resource Planning | ERP |
| Online-to-offline | O2O |
| Information and Communication Technology | ICT |
| Cultural and creative employment | CCE |
| Regular internet users | RIU |
| Availability of at least one computer and Internet connection in the family | AOC |
| Coefficient of variation | CV |
| Interquartile range | IQR |
| Support Vector Machine | SVM |
| k-Nearest Neighbors | KNN |
| Business to Customer | B2C |
| Within-cluster sum of squares | WCSS |
| Mean Absolute Error | MAE |
| Mean Squared Error | MSE |
| Root Mean Square Error | RMSE |

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