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Dissertation Summary

Stefan Apostol

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Digitalization of Entrepreneurial Ecosystems and Smart Specialization: The Importance of Place Specific Factors

(Dissertation Summary)

Stefan Apostol

Faculty of Business and Economics

Doctoral School of Regional Policy and Economics

Supervisor: **Prof. Dr. László Szerb**

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University of Pecs

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ABSTRACT

This dissertation looks into the complex interactions between the digitalization of entrepreneurial ecosystems, the concept of smart specialization, and the role of place-specific factors in the context of Europe. It is conducted an extensive examination of the adoption of digital web technologies across European regions to understand how the local environment serves as a connecting link between entrepreneurial ecosystems and smart specialization initiatives. By employing a mixed research methodology that integrates quantitative data analysis with in-depth case studies on selected web technologies, this study examines how geographical location, path dependence, and the embrace of digital web technologies impact regional growth and labor productivity.

At the core of the study are three main questions aimed at discovering the connective role of the local environment, the interconnections between geographical location and the adoption of digital technologies, and the association between digital complexity and regional economic performance within the European Union. The empirical approach includes spatial analysis, econometric models, and comparative case studies for specific web technologies, relying on a comprehensive self-developed dataset regarding the use of digital technologies in several European regions.

The research finds that place-specific factors play an important role in the adoption of digital web technologies, which, in turn, significantly affect regional innovation ecosystems and industry specialization. The result highlights the paradoxical negative link between digital complexity and regional productivity, as well as between the density of related technologies and their adoption rates in European Regions, emphasizing the need for integrated policy measures that foster digital innovation and the development of digital local infrastructure. In addition, the importance of the core-periphery dichotomy is discussed.

By offering concrete empirical evidence on the influence of geographical factors on the digital technology adoption of regional economies, this dissertation enriches the discourse on regional development, innovation policy, entrepreneurship, and digital transformation. It advances the understanding of digitalization's impact on regional economic growth, how digital web technologies are adopted, and provides valuable guidance for policymakers dedicated to strengthening regional innovation capabilities and competitiveness through tailored, place-based strategies.

1 INTRODUCTION

1.1 Introduction

While starting a new chapter of the digital transformation era, the role of digitalization, capacity to adopt new technologies, and entrepreneurship for regional economies becomes more and more essential in steering economic futures. The dissertation, titled “Digitalization of Entrepreneurial Ecosystems and Smart Specialization: The Importance of Place-Specific Factors” looks at the complex interplay between digital technologies and the regional intricacies of entrepreneurial ecosystems. While the significance of digitalization has been recognized, the details of how companies are adopting new digital web technologies remain unclear, and a robust framework for that is still not present. Besides, this shift towards a digital web environment and the factors affecting these digital systems have been to a certain extent overlooked by regional innovation policies, often treated as a black-box area, despite its essential role in directing innovation. This dissertation selects the European Union’s context to discover the effects of digitalization on smart specialization strategies (S3) and regional growth, but also how S3 influences the technology adoption, emphasizing the criticality of place-based factors.

The study’s need has its roots from the recent digital economy’s advance of both it’s theory and application, where the undertaking and integration of internet-based technologies are increasingly more and more necessary for regional productivity and economic output. Despite acknowledging the important role of digital web technologies in driving innovation and economic advance, a considerable knowledge gap persists regarding their adoption and absorption within diverse regional and industry-specific settings. This dissertation aims to reduce this research gap through a comprehensive analysis that enlightens the complex and context-dependent interactions between digital complexity, productivity, and digital web technology adoption across European NUTS2 regions.

Positioning itself between the discussions on digital change, innovation policies, and regional growth, this research critically reviews theories on entrepreneurial ecosystems, smart specialization, and the impact of geographic, spatial, and contextual factors. Including evidence from foundational theories but also recent studies, the dissertation advocates for a specific approach to understanding digitalization’s interaction with regional innovation capabilities and regional economic strategies.

The reason for adopting this investigation is drawn from identified literature gaps, lack of digital technologies' adoption studies, and pivotal observations about importance of digitization, presenting a compelling case for an in-depth examination of digital technologies' role in regional economic development, especially regarding place-specific elements. The study's justification is mainly driven by five main motives, collectively emphasizing the research's necessity.

First, it is the digitalization's dynamic nature and observed regional disparities, that highlight the uneven digital transformation benefits distribution. Despite a consensus on digital technologies as key economic growth pilots, understanding their varied impacts across Europe's diverse regions remains lacking. This research seeks to demystify the complex relationships between digital complexity, web technology adoption, and regional productivity under the umbrella of the frameworks of smart specialization and entrepreneurial ecosystems, where digitalization is often viewed as a separate matter.

Second, existing literature highlights the important role of geographical proximity, cognitive proximity, related web technologies, and interconnected research and entrepreneurial networks in fostering innovation and technological diversification. This ecosystem-based view, characterized by relatedness and a mesh of existing and emerging technologies, suggests a departure from conventional views on digital complexity and technology adoption, offering the opportunity for a more profound empirical investigation.

The third motive is the role of contextual and spatial dynamics in digital web technology adoption and digital complexity, while recognized for physical technologies, it demands further empirical exploration in the case of digital technologies. Although spatial factors and agglomeration effects are acknowledged for their innovation potential, the specific dynamics and spillover effects across different European regions are not completely understood. This study aims to fill this gap by closely examining how place-specific factors influence digital technology adoption and regional economic performance.

Fourth, integrating digitalization into smart specialization strategies offers a rich update for existing frameworks for research, but also novel empirical observations. Although the endowment of strategic regional factors and capabilities together with smart specialization strategies is believed to significantly boost innovation and economic growth, empirical evidence of digital technologies' impact on smart specialization strategies, especially from a place-based perspective, is not present.But their effects are also underestimated. This research explores the interaction between digital complexity, adoption of related web technologies, and smart specialization strategies that address the existing gap and promising valuable policy insights.

The fifth reason is that the fragmented literature on the adoption of digital technologies, entrepreneurial ecosystems, and regional economic growth requires a holistic integrative approach. The study responds to previous theoretical calls for an integrated framework that captures the effects of digitalization of firm functions in regional economies. In addition, its goal is to advance early scholarly discussions and provide practical advice for policymakers and industry pioneer stakeholders about digital technology adoption.

The research was started to bring empirical evidence regarding the challenges of firm digitization, but also about what the digital economy presents to regional development in a comprehensive way. By carefully analyzing the involved dynamics of regional economies, the study not only enriches academic debates but also guides the development of informed policies that focus on digital technologies' implementation for innovation and economic growth in various regional environments.

1.2 Problem Statement

The core problem this dissertation examines arises from the challenges associated with the digitalization process of entrepreneurial ecosystems, the planning and implementation of smart specialization strategies, and the crucial role of spatial and geographical considerations in these strategies. These challenges are layered, involving the difficulties of embedding digital technologies into regional development agendas, deciphering the patterns of technology adoption across diverse geographic settings, and unraveling the complex relationship between digital sophistication and regional economic performance.

There is a gap in research and policies when it comes to understanding how digital web technologies and their uptake are shaped by, and in turn shape, the local environment and geographical positions and economic growth. We are missing detailed methods when examining digital relatedness and its impact on the regional economic output that connect digital growth, entrepreneurial ecosystems, and the spatial and geographical aspects of different places.

The dissertation also highlights that strategies for digital innovation don't make enough use of the unique aspects of place-specific factors. Although we know the beneficial advantages of localized production and agglomeration economies, there is a lack of specific policies that use these factors to enhance the adoption of digital technologies and spur regional economic advancement.

The importance of this study is driven by the changing dynamics of digital economies, where the integration of web technologies, the degree of their complexity, and the density of relatedness are increasingly essential adoption of new technologies that later are transformed into regional competitiveness and economic health. However, the way in which these digital dimensions interact with spatial factors and contribute to the digital smart specialization of regions remains unexplored.

This dissertation tries to connect and solve these gaps in a holistic framework by conducting a comprehensive analysis of how the local environment is used as a connective link between digitalization and regional development strategies. Through a detailed examination of the linkages between physical location, digital technology adoption, digital complexity, and regional economic vitality, the research seeks to uncover the spatial dynamics essential to successful digital transformation strategies. By acknowledging the importance of geographic context in driving the digitalization trajectories of entrepreneurial ecosystems and smart specialization, this dissertation argues that a deep understanding of these dynamics can lead to more effective digitalization routes of entrepreneurial ecosystems and smart specialization.

Therefore, the study is positioned as a solution by examining empirical data and theoretical insights that can drive the formulation of place-specific digital innovation strategies. It states that policies should not only address the digital aspects of entrepreneurship and innovation, but also be customized to the unique spatial and geographic characteristics of each region. In this line Smart specialization efforts could be enhanced by adopting this strategy and including digitalization resulting in a more dynamic, economically robust, and digitally progressive regional economy.

1.3 Research Aims and Objectives

The research aims to examine the relationships between the digitalization of entrepreneurial ecosystems, smart specialization, and the importance of place-specific factors within the European context. Moreover, the study aims to explore how local environment acts as a connecting element between digital technology adoption, entrepreneurial ecosystems, and smart specialization strategies, and investigates the extent to which physical location and web technology adoption influence regional productivity, innovation capacities and growth. Using mixed-methods approach such as spatial models, specific cases about web technologies the research seeks to understand the impact of digital complexity, relatedness density, and technology adoption on regional economic development and provides insights for policymakers to enhance innovation capacity and competitiveness of regions through tailored, place-based strategies.

1.4 Research Questions

- Research Question 1: To what extent does the local context serve as a linking factor between entrepreneurial ecosystems and smart specialization frameworks?
- Research Question 2: What is the relationship between physical location and digital web technology adoption, does the place still matter?
- Research Question 3: What is the relationship between digital complexity, relatedness, technology adoption, and EU regional productivity?

1.5 Research Model

The dissertation framework, enriched the understanding of digitalization and the possible regional framework, and shows a compelling story that demonstrates the transformative impact of digital technologies on the intricate relationship between smart specialization strategies and the entrepreneurial ecosystem. This unified view highlights the necessity of nurturing technological progress and web technology adoption within a context-rich setting, spotlighting the critical roles played by relatedness density and digital complexity in driving regional innovation and economic performance.

Digitalization is seen as a primary catalyst for growth, aided by relatedness density, which enhances the spread and uptake of novel technologies through cognitive and geographical proximity, technological interconnectivity, and digital complexity. Which later elevate organizational and regional competitiveness by advancing internet infrastructure and digital skills proficiency. The exploration into digitalization augments the initial conceptual framework, that makes the shift from physical to digital environment and the incorporation of advanced digital web technologies as essential for the fulfillment of smart specialization strategies and the success of entrepreneurial ecosystems.

This framework, in conjunction with the understanding gained from digitalization, emphasizes the importance of identifying and fostering competitive advantages and areas of technological expertise. The idea is to encourage regions to utilize their unique resources and abilities by investing in digital technologies that are relevant to their strengths, following the guidance of the European Union's Smart Specialization Strategy. This approach promotes the development of specialized domains of activity and technological proficiency to enhance economic cohesion and competitive advantage.

By incorporating the concept of the entrepreneurial ecosystem into this narrative, I highlight the beneficial relationship that can be exploited by and between various stakeholders, including enterprises, governments, educational institutions, and financiers, in creating an atmosphere that promotes innovation and entrepreneurship. The statement underscores the importance of context, which encompasses spatial dynamics and cluster effects, in amplifying the economic advantages that arise from the adoption of technology.

This holistic model envisages a vibrant, recursive process of technological evolution and adoption, highlighted through insights into digitalization. It illustrates how digital technologies catalyze innovation, enhance competitive standing, and stimulate economic expansion, championing strategic approaches to digitalization efforts. The model indicates that contextual elements and policy measures play crucial roles in guiding economic progress toward enhanced productivity, growth, and innovation. It calls for a sophisticated policy design and execution approach, finely tuned to regional strengths and the broader context of global innovation networks, thereby acknowledging the intricate economic fabric where technology, knowledge, and situational factors intertwine.

This holistic model envisions a dynamic and iterative process of technical advancement and integration, emphasized by insights gained from digitalization. The framework model also demonstrates how digital technologies can accelerate innovation, improve competitive position, and boost economic growth by advocating for strategic approaches to digitalization initiatives such as related technologies. Moreover the framework shows that place specific factors and regional policy interventions are crucial in directing economic advancement towards increased productivity, growth, and innovation. Therefore, the digitalization process calls for a sophisticated policy design and execution approach, which is carefully tailored to the specific regional capabilities and infrastructure but also takes into account the broader context of global innovation networks. In this framework, it is recognized the complex economic environment where technology, knowledge, and contextual factors are interconnected.

This can be observed in the following framework:

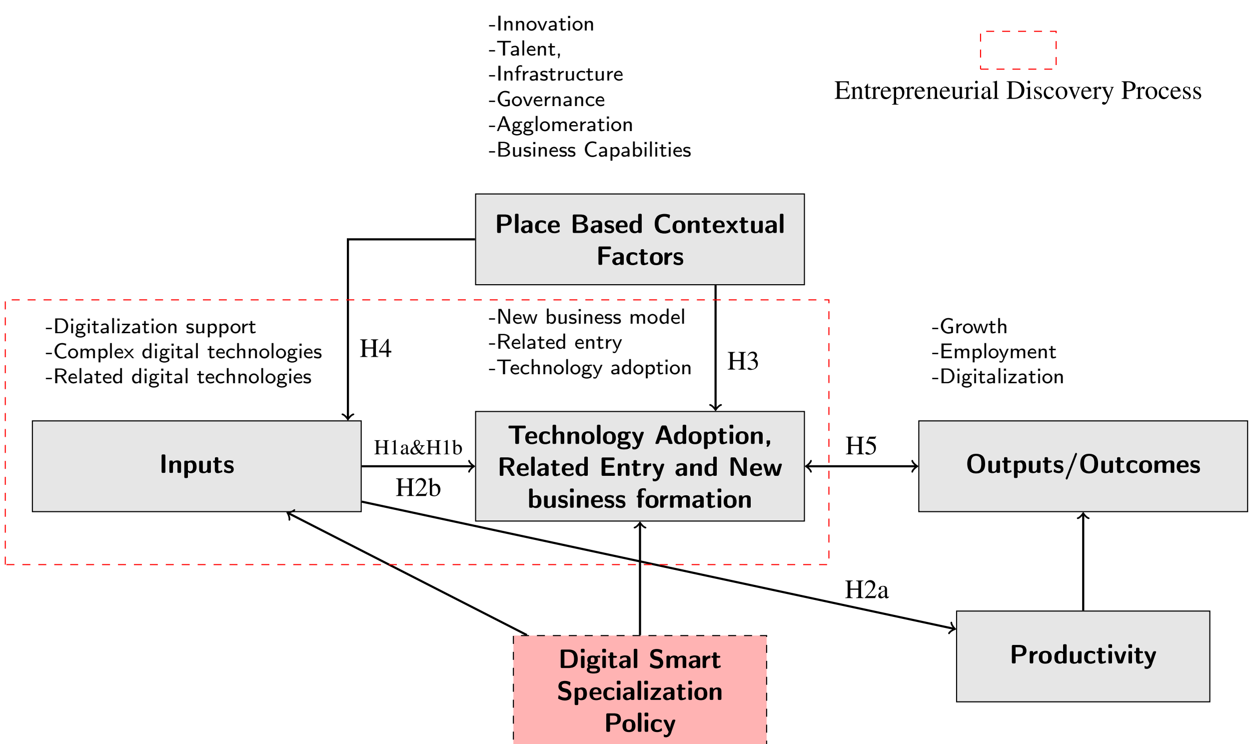

Figure 1: Conceptual framework of an Ecosystem-based Digital Smart Specialization Policy and Hypothesis Development

1.6 Research Hypotheses

The dissertation's hypothesis are elaborated based on the conceptual framework attempting to understand the complex interplay between relatedness density, digital complexity, technology adoption, and how they impact economic growth and regional development across European regions through an ecosystem based digital smart specialization framework. These hypotheses are:

1. *Hypothesis H1:*

   (a) *Hypothesis H1a:* There is a positive relationship between relatedness density and related entry. In the case of web technologies, high relatedness density indicates a closer knowledge relationship between existing and new technologies. Relatedness density is expected to enhance the likelihood of related entry, where firms in regions enter new digital technological domains that are closely related to their previous capabilities.

   (b) *Hypothesis H1b:* There is a positive relationship between relatedness density and technology adoption. High relatedness density, indicating a closer relationship between previous and new technologies, is expected to facilitate technology adoption.

2. *Hypothesis H2:*

   (a) *Hypothesis H2a:* Digital complexity positively influences labor productivity. Regions with higher digital complexity are hypothesized to exhibit higher productivity levels. When firms are digitized and have complex web technologies, they are expected to be more productive, therefore influencing the overall regional productivity.

   (b) *Hypothesis H2b:* There is a positive relationship between digital complexity and technology adoption. Higher levels of digital complexity within a region are expected to lead to higher rates of technology adoption. Here it is expected a spillover effect from firms with complex technologies to other firms in a region.

3. *Hypothesis H3:*

(a) *Hypothesis H3a:* Contextual factors (human capital, quality of governance, infrastructure) positively influence web technology adoption. This suggests that developed place specific factors and concentration of related activities facilitates the adoption of new technologies.

(b) *Hypothesis H3b:* Spatial spillovers have a positive relationship with web technology adoption. The hypothesis argues that if the neighboring region adopts a specific web technology, this will spill over and facilitate the adoption of new technologies in the current region.

(c) *Hypothesis H3c:* Agglomeration effects have a positive relationship with web technology adoption. The hypothesis argues that being in an innovation-oriented context with spatial and agglomeration of human economic activities facilitates the adoption of new web technologies.

4. *Hypothesis H4:*

   (a) *Hypothesis H4a:* Contextual factors (human capital, quality of governance, infrastructure) positively influence digital complexity. This suggests that the rich local environment and knowledge externalities enhance a region's digital complexity.

   (b) *Hypothesis H4b:* Agglomeration effects have a positive relationship with digital complexity. This suggests that the broader environment and concentration of human economic activities enhance a region's or organization's digital complexity.

5. Hypothesis H5: There is a reciprocal positive relationship between digital technology adoption and GDP per capita. This implies that not only does technology adoption contribute to higher GDP per capita, but also that regions with higher GDP per capita are more capable of adopting new technologies.

1.7 Research Contribution and Novelty

The research contribution and novelty of this dissertation are very important. The focus was on the complex dynamics between digital relatedness density, digital complexity, and web technology adoption across European regions. Here are the key highlights:

The dissertation provides a comprehensive analysis that explains and describes the complex and context-dependent relationships between digital complexity, productivity, and digital technology adoption. Moreover it advances the academic debate on effects of digital transformation by exploring the upper mentioned interconnected dynamics, contributing to a deeper understanding of the factors driving technology adoption and regional development from a ecosystem and economic geography perspective. The novel results focused on digital technologies, highlight the importance of fostering connected ecosystems. By adopting profound study approach to digital complexity, offering practical insights for policymakers and practitioners aiming to harness technological advancements for regional development. It looks on how the regional complexity influences, regional digital technology adoption, but also how following a path dependent approach affects adoption of new digital technologies

The novel dimension of this dissertation lie in its robust support for the hypothesis that a higher relatedness density significantly fosters the entry of related web technologies, emphasizing the role of cognitive proximity and interconnected ecosystems in regional innovation and technological adoption. Moreover it is the first time when the economic complexity and relatedness frameworks are applied to digital web technologies. Another aspect is that the study challenges preconceived notions about digital complexity, suggesting a paradox where regions with more advanced technologies might encounter diminishing returns in adopting new technologies as adoption requires higher capacity. Moreover, a spatial measurement of web technology adoption and used by firms was not performed. Such insights challenge the traditional understanding of digital adoption and highlight the need for a more detailed understanding of digital complexity's role in technology adoption and regional productivity.

1.8 Dissertation Structure

The dissertation presents a comprehensive examination of the entrepreneurial ecosystem and smart specialization strategies, especially in the context of digital transformation and its implications for regional economic development. It begins with an extensive literature review charting the evolution of the entrepreneurial ecosystem concept from its inception. This section meticulously dissects the framework and dynamics of these ecosystems, highlighting the critical roles of policy, finance, culture, and networks. It delves into the transformative impact of digital technologies, exploring how they reshape industries and foster the emergence of platform ecosystems.

In the Methodology chapter, the dissertation highlights its research design and analytical strategies, focusing on spatial panel fixed effects models to explore the interplay between digital complexity, productivity, and technology adoption across European regions. This methodological approach is critical for understanding spatial dependencies and the detailed relationships that underpin regional economic performance and the diffusion of digital technologies.

The narrative progresses to an analysis of Digital Complexity and Productivity, presenting empirical evidence to elucidate how digital technologies influence labor productivity. This chapter uncovers significant spatial spillovers, revealing the interconnected nature of regional economies and the paradoxical role of digital complexity in driving economic performance.

Later, the examination shifts towards Technology Adoption in the Digital Era, investigating the factors that support or impede the adoption of digital technologies. Through a detailed analysis, it identifies a paradox where regions of high digital complexity do not always lead in technology adoption, pointing towards the saturation effects and the importance of relatedness density.

The Role of Spatial Factors and Ecosystem Dynamics chapter further explores the geographical and economic factors shaping digital transformation. It provides insights into the core-periphery dynamics, highlighting how spatial factors and ecosystem dynamics are crucial in understanding the uneven distribution of digital technologies.

Concluding with the Policy Implications chapter, the dissertation synthesizes its findings, offering actionable insights for policymakers and regional planners. It advocates comprehensive strategies that address both technological advancements and socioeconomic considerations, aiming to enhance regional competitiveness in the digital age. This chapter also sets the stage for future research, suggesting avenues for deeper exploration into the details of digital ecosystems and their broader economic implications.

1.9 Research Gaps

Web technologies are the core infrastructure of platforms and online activity, enabling online communication, transactions and web innovation (Yoo et al., 2010; Tsalgatidou and Pilioura, 2002).Though digitalization expected to diminish distance, or even the "death" of distance, studies show that local contexts significantly shape digital technology adoption and usage (Graham, 2013; Castells, 2010). While digital technologies' transformative potential on regions is recognized (Kenney and Zysman, 2016), the detailed pathways of how digital complexity and technology adoption directly enhance regional productivity need empirical evidence (Acs et al., 2017; Autio et al., 2018).The concept of relatedness states that regions are more likely to expand into technologies or industries aligned with their existing strengths, meaning developing new products, industries, technologies, and occupations related to their current capabilities (Hidalgo et al. 2007; Neffke et al. 2011; Boschma et al. 2015; Balland et al. 2019).Proximity to tech hubs aids absorption due to knowledge spillovers (Jaffe et al., 1993). Therefore, a framework for digital web technology adoption is missing and needed and it is not clear how digital technology adoption is integrated with entrepreneurial ecosystems and smart specialization strategies. The role of place-based factors in shaping digital technology adoption and diffusion across contexts remains little explored. Evidence on digital innovation strategies tailored to specific regional contexts is lacking. Contradictions exist regarding digitalization's impact on regional inequality and the digital divide, necessitating further research into these complex relationships (Cohen and Kietzmann, 2014; Cairncross, 2002; Autio et al., 2018).

2 Research Design and Methodology chapter

This section presents a detailed and comprehensive approach towards analyzing the digital adoption divide across European regions, emphasizing the interplay between evolutionary factors and regional characteristics on technology adoption and subsequent economic growth. This section is carefully crafted, employing a multifaceted methodology that includes the selection and geolocation of firms, identification and monitoring of web technologies, and the collection of technology adoption and contextual factors.

The research utilizes Crunchbase to identify high-growth technology firms and startups, focusing on those at the forefront of digital innovation. This selection process is crucial for understanding regional disparities in technological adoption and its economic outcomes, with firms chosen based on their geographical location, industry sector, and website ownership.

In the case of identification and Monitoring of Web Technologies, the BuiltWith API tracks the adoption of digital web technologies by these companies, enabling a longitudinal study of technology diffusion across NUTS 2 European regions. This analysis is pivotal for examining Digital Complexity and Relatedness density across regions, identifying a spectrum of digital web technologies from basic utilities to advanced functionalities.

The study quantifies the adoption rate of selected web technologies, merging company data with technological usage information. It also integrates various contextual factors like the quality of government, infrastructure, and business sophistication to assess their influence on technology adoption.

The thesis leverages data from diverse and comprehensive sources, ensuring a rich empirical foundation:

Crunchbase provides data on high-growth tech firms and startups, crucial for identifying firms at the forefront of innovation. BuiltWith offers detailed records of technology deployment on web domains, enabling the study of technology diffusion. ARDECO supplies economic performance indicators such as GDP per capita and employment, vital for understanding the economic context. EUROSTAT and Quality of Government Institute contribute data on talent and governance quality, contextualizing the technological adoption within broader socio-economic frameworks. EU Regional Competitiveness Index (RCI) provides insights into the quality of infrastructure and business sophistication, influencing the adoption and effectiveness of digital technologies.

The methodology incorporates sophisticated analytical techniques, including spatial econometric models, logistic models and the method of reflections, to explore the interconnectedness of digital web technologies within regions and their impact on economic outcomes like labor productivity. These models evaluate the probability of the entry of related web technologies in a given region and assess the impact of digital complexity on labor productivity or technology adoption, incorporating various independent variables and utilizing fixed effects to account for unobserved heterogeneity.

In this comprehensive examination, I combine rich data sources with advanced empirical models, underlines the thesis's exploration of digital adoption divides and the significant role of regional characteristics and evolutionary factors in shaping digital technology adoption and economic growth. Through this approach, the research aims to contribute valuable insights to the discourse on digitalization and regional development, offering a detailed understanding of the factors influencing digital technological advancement and economic dynamics across European regions.

3 Results of the research:

3.1 The role of relatedness in digital technology adoption-regional level

The investigation of this dissertation started with understanding the role of relatedness in digital technology adoption, and a network visualization of digital web technologies, where each node corresponds to a different technology.This is visible in Figure 2. The size of each node is indicative of the eigenvector centrality of the respective digital web technology. Eigenvector centrality is a measure of the influence of a node within a network; larger nodes in this context imply that a technology has a greater influence within the web of digital technologies, likely due to its widespread use or integration with other technologies.

The relatedness between web technologies is depicted through the lines connecting the nodes. A greater number of lines between technologies indicates a higher degree of relatedness, suggesting that these technologies are often used together or have complementary functionalities. For instance, technologies related to analytics, content management systems (CMS), hosting, and shopping could be more interconnected due to their joint role in the ecosystem of an e-commerce platform.Technology space analysis can help to identify key enabling technologies that drive digital industry coalescence and new digital industry emergence (Trincado-Munoz et al. 2023). This analysis also elucidates which technologies singularly influence industry digitalization and which technologies operate synergistically as a system.

The colors of the nodes differentiate the technology groups, providing a visual segmentation

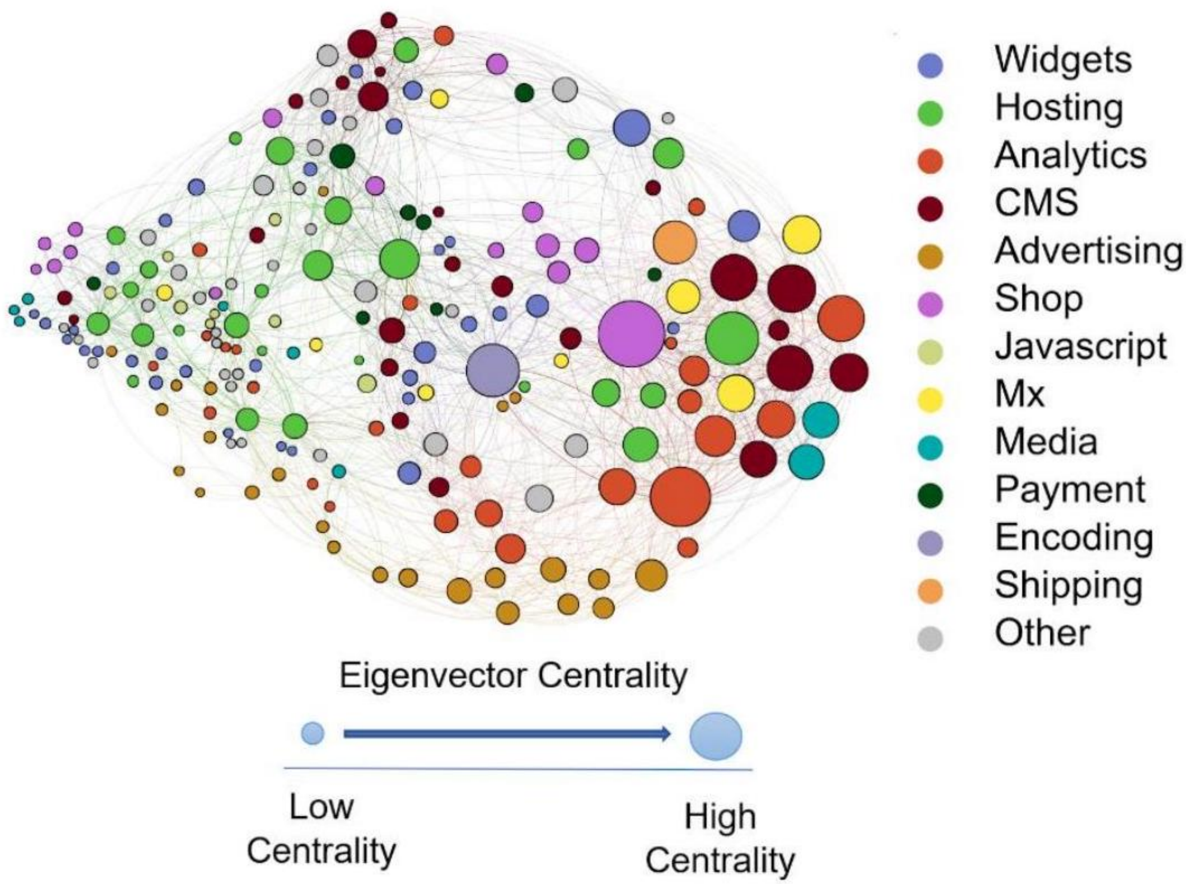

Figure 2: The digital space of the web technologies. Source: Authors' own elaboration.

of the various categories like CMS, advertising, media, payment, etc. This color coding helps to quickly identify clusters of related technologies within the network, showing how certain categories of technologies are central to the digital ecosystem.

Discussing this plot, it can be deduced that technologies with high eigenvector centrality, such as those related to Hosting, Analytics, Shop or CMS, are likely crucial for the functionality and efficiency of a broad range of web applications. These central technologies could be seen as the backbone of the digital infrastructure, enabling a multitude of other web-based services and functions to operate effectively. The strategic integration of digital technologies and the shift towards digital organizational models via the adoption of web technologies might serve as key catalysts for the growth of digital economies (Polyakov and Kovshun 2021). And in this case the relatedness-based framework of technology adoption could be a solution, as it makes digital tech's adoption easier and emergence of new industries higher (Boschma, Minondo, and

Navarro 2013).

I also created several plots where average Relatedness Density across European regions from 2000 to 2022 can be visualised.When assessing visually the regional average relatedness density (RD) of web technologies between Central Eastern Europe (CEE) and Central and Western Europe, notable contrasts emerge. CEE displays generally lower RD scores, indicative of a less interconnected web technology sector.

In the same line of the research, Table 1 represents the results of logistic regression models that predict the likelihood of entry of related web technologies in a given region, with ' 1 ' indicating the entry. The positive coefficients Relatedness density across all models indicate that a higher relatedness density significantly increases the likelihood of entering related web technologies. The positive and significant Population density coefficient in model (2) suggests that more densely populated regions are more likely to see the entry of related web technologies. The significance disappears in the full model without fixed effects but reappears positively in the full model with fixed effects.This corresponds with Jacobs' (1969) concept of externalities and the subsequent cluster theory, which suggest that the variety of skills and ideas present in densely populated urban areas act as catalysts for innovation. This concept is equally valid for the entry of web technologies. Based on the comprehensive analysis of research findings, which illustrates a positive correlation between relatedness density and the propensity for related entry in web technologies across European regions, I confidently accepted Hypothesis H1a. This acceptance underscores the pivotal role of relatedness density in facilitating technological evolution and innovation at the regional level.

Table 1: Related entry model: logit models.

	Dependent variable: Related Entry $(=1)$			
	(1) Baseline	(2) Controls	(3) Full model	(4) Full model Fixed Effects
Constant	-1.752^{***} (0.00913)	-1.822^{***} (0.0154)	-1.752^{***} (0.0102)	
Relatedness density	0.0281^{***} (0.000869)		0.0300^{***} (0.000936)	0.0270^{***} (0.00112)

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Table 1 continued from previous page

(log) GDP/cap		1.929^{**} (0.858)	-1.163^{*} (0.676)	0.457 (1.183)
(log) Total population		1.713^{**} (0.846)	-0.996 (0.679)	-9.238^{***} (1.312)
(log) GVA		-1.798^{**} (0.844)	0.920 (0.665)	0.293 (1.152)
(log) Total employment		0.129 (0.124)	-0.0749 (0.0800)	-1.155^{***} (0.289)
(log) Population density		0.0474^{***} (0.0161)	0.0159 (0.0113)	7.055^{***} (1.279)
(log) Patent applications		0.00486 (0.0146)	0.0957^{***} (0.0113)	0.0810^{***} (0.0302)
Observations	218,268	218,268	218,268	87,732
R-squared (Pseudo)	0.02	0.003	0.02	-
Region-Tech Fixed Effects	NO	NO	NO	YES
Year FEs	NO	NO	NO	YES

Notes: All predictor variables have been standardized around the mean and are delayed by one time period. Standard errors that are robust to heteroscedasticity (and clustered by region) are presented in brackets for all models except the two-way fixed effects (4). Coefficient values reach statistical significance at the $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$ levels.

3.2 Digital Complexity

A initial common observation based on the Digital Complexity plots shows that regions with central capitals appear to undermine the digital complexity of nearby regions. Certain locations may find the availability and accessibility of a competent labor force, which is nurtured by institutions of higher education, to be of the utmost importance. I also found significant disparities in digital complexity across Europe. While there are clusters of advanced digital development, there are also areas that lag behind, highlighting a digital divide within certain parts of Europe.

The analysis of the impact of digital complexity on productivity, as reflected in the following provided Table 2, underscores a multisided relationship that is highly dependent upon the modeling approach and the specificities of the data considered. In a pooled ordinary least squares (OLS) framework, digital complexity demonstrates a uniformly positive effect on productivity.

This general positive association may be attributed to the overarching benefits of digital technology adoption, which, even at basic levels, can significantly enhance productivity across various sectors. However, this simplified aggregation inherent in pooling OLS models may not reveal the complex relationship between digital complexity and productivity that is evident when spatial and temporal dynamics are taken into account.

Table 2: The effect of Digital Complexity on productivity

	Dependent variable:			
	log(Productivity)			
	(1)	(2)	(3)	(4)
Digital Complexity	0.001^{***}	0.002^{***}		0.001^{**}
	(0.0002)	(0.001)		(0.0003)
Spatial lag of productivity	0.996^{***}		0.898^{***}	0.893^{***}
	(0.011)		(0.054)	(0.050)
Spatial Lag of GDP/cap			0.093^{*}	-0.001
			(0.049)	(0.045)
Spatial Lag of Digital Complexity		-0.0001	-0.0002	-0.0004
		(0.001)	(0.0003)	(0.0004)
ln(Population Density)				0.010^{**}
				(0.004)
ln(Patent Applications)				0.049^{***}
				(0.004)
Constant	0.004	10.646^{***}	0.178	0.896^{***}
	(0.116)	(0.034)	(0.145)	(0.147)
Region FE	NO	NO	NO	NO
Time FE	No	No	No	No
Observations	1,505	1,505	1,505	1,505
R^2	0.852	0.011	0.851	0.875
Adjusted R^2	0.852	0.010	0.851	0.874
F Statistic	$4,316.912^{***}$ (df=2;1502)	8.328^{***} (df=2 ; 1502)	$2,854.938^{***}$ (df=3; 1501)	$1,739.960^{***}$ ($df = 6; 1498$)

Notes: The model in use is a Pooling OLS model without controlling for time and space. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

The apparent positive relationship in the pooling OLS model suggests that initial or widespread adoption of web technologies can lead to broad productivity gains. However, this analysis might not capture the differentiated impacts that emerge over longer periods or with more substantial changes in digital complexity. The transition to spatial panel fixed effects models, which account for regional and temporal variations, reveals a more complex relationship. The mixed results, where digital complexity initially shows a positive impact on productivity but then demonstrates negative coefficients in models adjusted for spatial and temporal dynamics, suggest that the relationship between digital complexity and productivity is contingent upon specific regional characteristics, or time. This result is further investigated in the next model.

Moreover, the significant spatial dependencies highlighted in the models emphasize the importance of geographical proximity in determining how digital complexity influences other regions' productivity. Such findings point to the necessity of adopting a meticulous analytical lens, incorporating both spatial and temporal variations to fully understand the complex dynamics at play. This complexity, particularly the negative coefficients observed in more refined models, may imply that while digital complexity contributes to productivity, its effects are not universally positive across all regions and circumstances. Factors such as the maturity of the digital infrastructure, the adaptability of the workforce, and the existing economic structure of a region may play critical roles in determining the extent to which digital complexity can translate into productivity gains.

In the next empirical part (Table 3), when controlled for region fixed effects in model 1 and 2, Digital complexity has a significant positive relationship with changes in labour productivity. Later when time fixed effects are introduced (Model 3), although positive, this relationship is not significant. These effects suggest that while digital complexity have a stronger association with productivity in earlier years, this effect tends to decrease in later years when these web technologies mature, become ubiquitous and their effects are homogenous in all regions. However, adding too much FEs (region and time) on top on the already hard assumptions coming from the spatial model, reduces largely the variation of my explanatory variable (Digital complexity).

Given the previous considerations, and additional tests performed, it would be more accurate to state that I partially accept Hypothesis H2a. This partial acceptance acknowledges the positive impact of digital complexity on productivity under certain conditions, while also recognizing the limitations and variability of this impact across different spatial and temporal contexts. The evidence suggests that the influence of digital complexity on productivity is significant but complex, influenced by a multitude of factors and policies at regional level that can enhance or mitigate its effectiveness, but also the right timing might have an effect also.Later in the analysis I create a Digital Smart Specialization Framework, where it is shown which regions and what

Table 3: Spatial Error Productivity Models

Dependent variable: $\Delta \log$(Productivity)			
Variable	SEM (Model 1)	SARAR (Model 2)	SARAR (Model 3)
(Intercept)	-	-	-
Digital complexity (log)	0.0101* (0.0042)	0.0090* (0.0040)	0.0029 (0.0041)
GDP pc (log)	-0.0092 (0.0160)	0.0003 (0.0163)	0.0573*** (0.0164)
Population density (log)	0.0789 (0.0510)	0.0965** (0.0486)	0.182*** (0.0533)
Patent applications (log)	-0.0116* (0.0049)	-0.0119** (0.0048)	-0.0218*** (0.0053)
rho	-	-0.2548*** (0.0555)	0.5380*** (0.0660)
delta	0.6917*** (0.0188)	0.7898*** (0.0200)	0.0300 (0.0998)
Observations	1290	1290	1290
Region Fixed Effects	Yes	Yes	Yes
Time Fixed Effects	NO	NO	Yes
Sigma	0.0698	0.0700	0.0577
AIC	-6296.22	-6307.15	-6408.21
BIC	-6270.41	-6276.17	-6377.23

Notes: All coefficients are statistically significant at the following levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors are shown in parentheses. Observations are mean-centered. The dependent variable is the change in labor productivity. The models include region and year fixed effects where indicated. Where SEM = Spatial error model, and SARAR = Spatial autoregressive combined model.

part they should improve (Digital Complexity or Digital Relatedness).

To prove the idea that the geography and local factors shape the technology adoption and is not the technology that shrinks the space, you can see the following figure, Figure 3. Let's focus specifically on the spatial distribution of live chat technology adoption in Eastern Europe and the Central-West/South regions.In Eastern Europe, including countries like Poland, the Czech Republic, Slovakia, Romania, Bulgaria, and the Baltic States, the LISA map indicates High-High (HH) associations, which are shown in dark purple. This suggests that these regions have high levels of live chat technology adoption and are also surrounded by regions with similar levels of adoption. Comparatively, Central-West or Central-South Europe may show different patterns, potentially mixing High-High and Low-High (LH) associations. The LH associations could indicate that while some central areas have high adoption, they are adjacent to areas with lower adoption levels, which may reflect varying economic conditions, the presence of rural areas, or differing priorities in technological investments. The high levels of adoption in Eastern European countries suggest that these regions have not only caught up with central-western regions, but might be leading in implementing complex web technologies for business communications solutions. However, this could also be associated with the region's growing role as a hub for offshoring activities, including client service centers and call centers.The presence of offshoring activities, particularly those focused on customer service and live chat, may explain the high adoption rates of live chat technologies in the region.This is later tested in the empirical model through the industrial structure variable.

Companies that offshore these operations must integrate live chat systems that are capable of handling complex customer interactions, often involving coordination with CRM systems, databases, and various application interfaces. The adoption of live chat technology in these areas suggests not only the presence of the necessary technological infrastructure, but also a business environment that values and invests in advanced communication tools for customer service excellence. Geographically speaking, Eastern Europe is well-positioned to serve as a bridge between Western Europe and Asia. The time zone overlap with Western European countries allows for real-time communication, which is a critical aspect of live chat services. But also often Eastern Europe and Baltic countries offer a more cost-effective environment for businesses due to lower wage levels compared to Western Europe. We should also consider the skilled workforce that speaks many foreign languages and recent developments in internet infrastructure. in these regions.

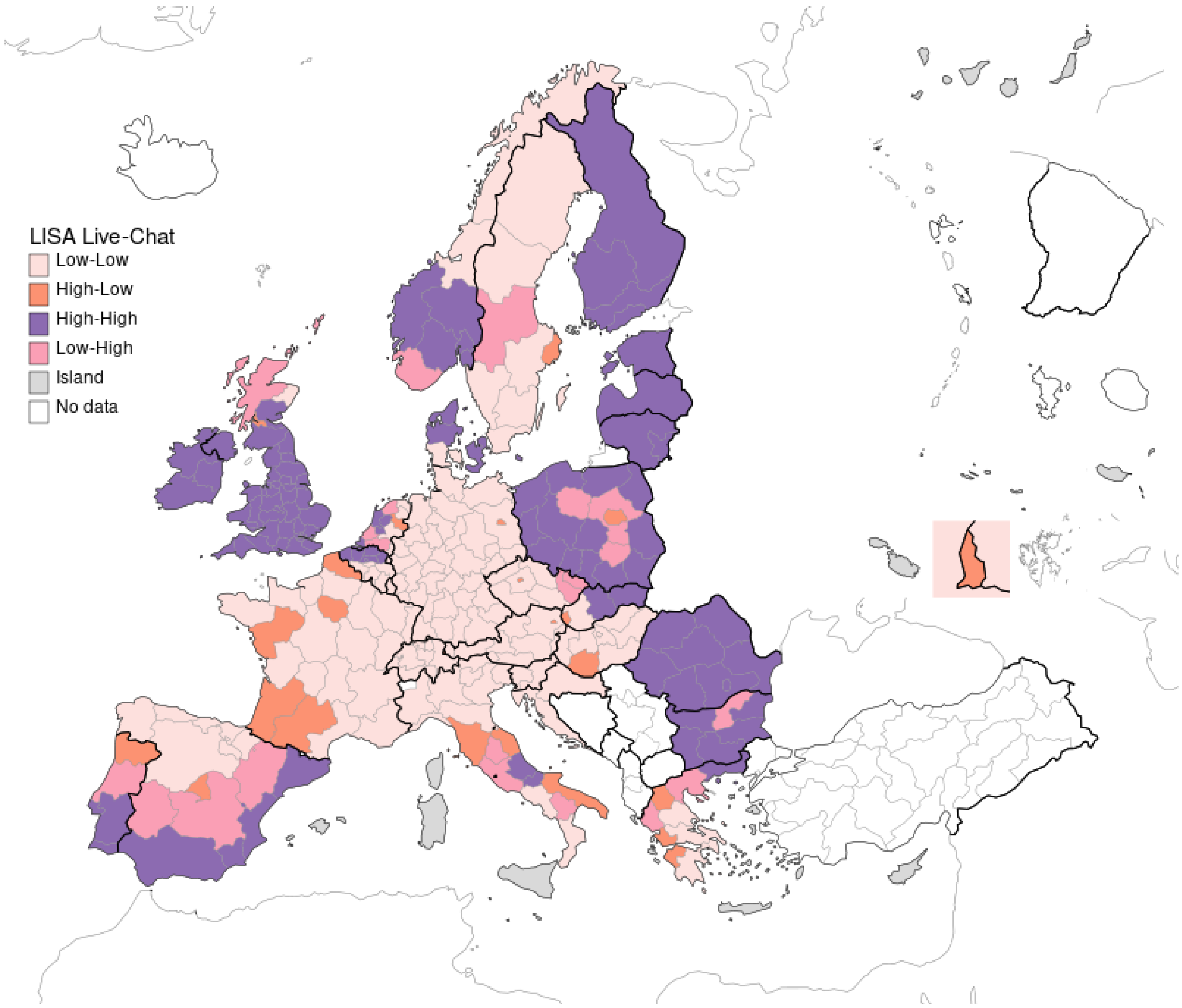

Figure 3: Local Indicators of Spatial Association (LISA) for the live-chat web technology adoption. Source: Authors' own elaboration.

3.3 The impact of the digitalization, Ecosystem and Spatial factors on Technology Adoption

In the analysis of the factors influencing technology adoption across different digital technologies, Table 4 provides important insights that deserve a detailed discussion within the context of this dissertation. The findings from this table guide a straightforward interpretation of Hypotheses 1b and 2b, which concern the roles of relatedness density and digital complexity in technology adoption, respectively.

Firstly, Hypothesis 1b shows a positive relationship between relatedness density and technology adoption. This hypothesis is robustly supported by the data, which exhibits significant positive coefficients for the log of relatedness density across all analyzed technology categories. This consistent pattern underscores the premise that regions with a higher density of related technological capabilities and knowledge networks are more adept at adopting new digital technologies. Such a finding aligns with the theoretical frameworks suggesting that cognitive proximity and shared knowledge bases facilitate the diffusion and assimilation of innovative technologies. There are no deviations from this positive relationship across the different models. This reinforces the importance of fostering interconnected innovational ecosystems for enhancing the adoption rates of new digital technologies.

Conversely, Hypothesis 2b, which anticipates a positive relationship between digital complexity and technology adoption, encounters a contradictory narrative in the empirical evidence. Despite initial expectations, digital complexity is associated with significant negative coefficients in nearly all technology categories examined. This counter-intuitive result suggests that regions with higher levels of digital complexity might face diminishing returns in adopting additional new technologies. Potential explanations for this phenomenon could include saturation effects, where highly digitized regions prioritize the optimization of existing technologies over the adoption of new ones, or encounter barriers related to compatibility issues and the incremental costs of adopting further technologies. Such findings necessitate a reevaluation of the assumed linear benefits of digital complexity on technology adoption and point towards the complexity of navigating digital ecosystems that are already highly developed. In the case of the place specific factors, we can see that often Patent application have a negative relationship with technology adoption which might suggest that those regions that more productive in terms of physical technologies are less productive in adoption web technologies.However, the human capital or talent almost always has a positive relationship with web technology adoption, suggesting that only those regions that have more education population might benefit from the digital transformation, also discussed as a digital divide.

Infrastructure also plays a significant role in the adoption of web technologies. This leads to the acceptance of the Hypothesis 3a which test the impact of place specific factors on web technology adoption.

The analysis demonstrates that being in a core or periphery region significantly affects technology adoption rates, with core regions not always leading in the adoption of new technologies like Javascript library and Live Chat. This finding challenges traditional notions of innovation diffusion, suggesting that peripheral regions may also be active participants in adopting certain technologies, possibly due to specific needs, niche markets, or the presence of unique ecosystems that support such adoptions.When talking about Spatial Spillovers this indicates that technology adoption in one region is likely influenced by the adoption rates in neighboring regions, highlighting the importance of spatial spillovers.

Overall, Hypothesis 3 is accepted. The analysis brings to the forefront the critical role of geographical factors and spatial spillovers in the adoption of technology. The analysis underscores the significance of geographical factors and spatial spillovers in technology adoption, with core-periphery dynamics and the presence of spatial autocorrelation playing crucial roles, seen in Table 5. It can be concluded that the landscape of technology adoption is shaped by a multitude of factors, where the presence of conducive elements such as skilled labor, business sophistication, infrastructure and relatedness density coexists with challenges posed by digital complexity, governance quality, and infrastructural needs.

Table 4: The Influence of Digital Complexity and Relatedness on Technology Adoption

	Dependent variable: TA (Technology Adoption)									
	Ad analytics	Javascript library	Affiliate programs	Marketing automation	Audience measurement	Application performance	Live chat	CMS	Currency	Framework
Digital complexity	−0.001***	−0.003***	−0.001***	-0.001	−0.001***	−0.001***	−0.001***	−0.001***	−0.002***	−0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
log(RelatednessDensity)	0.019***	0.265***	0.006***	0.034***	0.135***	0.136***	0.089***	0.017***	0.045***	0.109***
	(0.002)	(0.008)	(0.002)	(0.004)	(0.006)	(0.007)	(0.004)	(0.001)	(0.010)	(0.010)
log(Population density)	0.001	-0.005	0.001	-0.002	-0.002	-0.002	-0.001	-0.001	-0.005	0.001
	(0.001)	(0.004)	(0.001)	(0.002)	(0.003)	(0.003)	(0.002)	(0.001)	(0.005)	(0.005)
Patent Applications	-0.001	−0.001*	−0.001***	−0.001***	−0.001***	−0.001***	−0.001***	−0.001***	−0.001***	−0.001***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Business Sophistication	0.037***	0.496***	−0.017***	-0.001	0.090***	0.117***	−0.058***	0.004	−0.166***	0.066***
	(0.005)	(0.019)	(0.005)	(0.010)	(0.015)	(0.016)	(0.010)	(0.003)	(0.026)	(0.023)
Talent	0.003***	0.010***	0.002***	0.011***	0.003***	0.005***	0.010***	0.001***	0.011***	0.024***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Quality of Governance	-0.007	−0.161***	0.010	0.122***	-0.010	0.015	0.045**	0.047***	0.421***	0.316***
	(0.012)	(0.042)	(0.011)	(0.023)	(0.034)	(0.035)	(0.022)	(0.006)	(0.056)	(0.051)
Quality of Infrastructure	0.033***	0.063**	0.023***	0.155***	0.047**	0.055**	0.138***	0.007*	0.157***	0.349***
	(0.007)	(0.026)	(0.007)	(0.014)	(0.021)	(0.022)	(0.013)	(0.004)	(0.035)	(0.032)
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	No	No	No	No	No	No	No	No	No
Observations	2,013	2,088	2,024	2,066	2,088	2,088	2,077	1,980	2,088	2,088
R^2	0.480	0.848	0.161	0.585	0.507	0.537	0.675	0.325	0.221	0.653
Adjusted R^2	0.426	0.832	0.073	0.542	0.455	0.488	0.641	0.255	0.140	0.617
F Statistic	210.184*** (df = 8; 1822)	1,320.852*** (df = 8; 1890)	43.798*** (df = 8; 1832)	329.933*** (df = 8; 1870)	242.500*** (df = 8; 1890)	273.658*** (df = 8; 1890)	488.413*** (df = 8; 1880)	108.014*** (df = 8; 1792)	66.962*** (df = 8; 1890)	445.377*** (df = 8; 1890)

Notes: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.All models are panel linear models estimated using the 'plm' package in R with a 'within'(fixed effects) model specification and individual effects. Dataset corresponding to specific technology: Ad Analytics,Javascript, Affiliate Programs, Marketing Automation, Audience Measurement, Application Performance, Live Chat, CMS, Currency, and Framework. Regional fixed effects are included in all models, while time fixed effects are not considered.

Table 5: The effect of spatial spillovers on Technology adoption.Does the place still matter?

	Dependent variable: Technology adoption									
	Ad analytics	Javascript library	Affiliate programs	Marketing automation	Audience measurement	Application performance	Live chat	CMS	Currency	Framework
ρ	0.125	0.107***		0.102	0.213***	0.210***	0.146	0.310***	0.501***	0.504***
	(0.088)	(0.029)		(0.311)	(0.029)	(0.029)	(0.161)	(0.041)	(0.023)	(0.023)
ρ_{t-1}	0.195**	0.331***		0.514	0.090**	0.094*	0.500***	0.289***	0.312***	0.157***
	(0.081)	(0.027)		(0.492)	(0.043)	(0.048)	(0.219)	(0.033)	(0.024)	(0.032)
ln (GDP/cap)	0.061***	0.248**	0.050***	0.075	0.141	0.166	0.141***	0.009	0.038	0.215***
	(0.019)	(0.122)	(0.011)	(0.046)	(0.098)	(0.110)	(0.031)	(0.016)	(0.024)	(0.024)
ln (Total Population)	0.144	-0.303	0.084	0.257	-0.073	0.054	0.051	-0.042	0.296***	0.067
	(0.088)	(0.965)	(0.071)	(0.332)	(0.784)	(0.872)	(0.233)	(0.040)	(0.112)	(0.099)
ln (Total Employment)	-0.064	-0.042	0.022**	0.099	-0.007	-0.003	0.008	0.004	0.248***	0.063
	(0.078)	(0.390)	(0.025)	(0.153)	(0.322)	(0.358)	(0.107)	(0.030)	(0.067)	(0.059)
Quality of Governance	-0.033	-0.043	-0.024	0.063	-0.092	-0.078	-0.078	0.013	0.257***	−0.113**
	(0.063)	(0.121)	(0.034)	(0.281)	(0.105)	(0.115)	(0.198)	(0.032)	(0.061)	(0.053)
Corruption	-0.025	−0.128***	0.032	-0.054	0.002	-0.007	0.003	0.006	−0.200***	0.240***
	(0.048)	(0.043)	(0.028)	(0.211)	(0.040)	(0.043)	(0.147)	(0.036)	(0.049)	(0.043)
Quality of Infrastructure	0.024**	0.055**	0.024***	0.077***	0.057**	0.050*	0.094***	0.006	0.023	0.225***
	(0.011)	(0.027)	(0.008)	(0.024)	(0.024)	(0.026)	(0.016)	(0.036)	(0.026)	(0.024)
Business Sophistication	0.052***	0.299***	-0.016	-0.011	0.039	0.071*	-0.008	0.020	−0.065***	0.073***
	(0.013)	(0.046)	(0.011)	(0.044)	(0.040)	(0.042)	(0.031)	(0.026)	(0.023)	(0.021)
Talent	0.001***	0.007***	0.001**	0.005***	0.004***	0.005***	0.004***	0.001***	0.005***	0.008***
	(0.0004)	(0.001)	(0.0005)	(0.001)	(0.001)	(0.001)	(0.001)	(0.0003)	(0.001)	(0.001)
Constant			−1.873*							
			(1.084)							
Adj. (Pseudo) R^2	0.569	0.803	0.642	0.680	0.327	0.391	0.780	0.372	0.549	0.775
Region fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2013	2090	2024	2068	2090	2090	2079	1980	2090	2090
LM test for spatial lag	62.69***	424.54***	0.106	276.57***	101.01***	87.54***	553.83***	172.81***	1076.6***	802.32***
LM test for spatial error	37.93***	120.79**	2.15	123.99***	66.88***	47.96***	275.38***	132.17***	937***	561.94***

Notes: Rho represents the spatial lag of the dependent variable.All models are panel linear models estimated using the 'splm' package in R with a 'Spatial model with individual (Regions) effects' model specification. The dependent variable is Technology Adoption.Each model uses a unique dataset corresponding to a specific web technology. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

For Hypothesis 4, the findings suggest a partial acceptance. The influence of contextual factors on digital complexity and relatedness density is evident but manifests in complex and sometimes counter-intuitive ways. While certain factors like quality of infrastructure and business sophistication positively influence digital complexity, suggesting that a well-developed infrastructure and a sophisticated business environment are conducive to enhancing digital complexity, other factors do not uniformly lead to increased digital complexity. This partial acceptance indicates that while some contextual factors are pivotal in fostering a complex digital landscape, not all factors contribute equally, and the overall influence is not entirely clear.

3.4 Does Technology adoption affect economic growth, or economic growth affect Technology adoption?

Finally, the simultaneous relationship between technology adoption and economic growth is examined in Table 5 and Table 6. The examination of this relationship is aimed to test the literature which suggests a simultaneous relationship. First, Table 6 which is titled "The relationship between Technology Adoption and Economic Growth" presents a comprehensive analysis of how the adoption of various digital web technologies influences GDP per capita, as a proxy for economic growth. The dependent variable across all models is the logarithm of GDP per capita, which allows for a detailed understanding of growth rates across different technological adoptions. I examine a range of web technologies as indicated in the table notes.

The results indicate a mixed impact, with the adoption of certain web technologies like the Javascript Library significantly positively affecting economic growth, as evidenced by a positive and statistically significant coefficient. This suggests that the adoption of Javascript Library technologies, a technology essential to the development of interactive and functional web applications, contributes to economic productivity and growth. Moreover, this type of technology drives innovation and operational efficiency. This allows companies to interact and create value in various sectors such as in e-commerce, online services, and digital marketing by enhancing their offerings and customer engagement possibilities. This ease of adoption of this technology ensures that businesses can quickly leverage these technologies to stay competitive and innovative, which is translated into growth.

On the other hand, the adoption of other technologies, such as Live Chat and CMS, is associated with negative coefficients. This implies a potential short-term drag on economic growth, or this effect is not seen in all the regions, therefore the result is negative. This could reflect also the costs and adjustments required to integrate these technologies into existing systems and workflows, but also that this technology is used only in specific regions that need this technology.

Live-chat technologies, which enable real-time communication between businesses and their customers, exhibit a more complex (negative) relationship with GDP per capita. While intuitively one might expect a positive impact due to improvements in customer service and engagement, the negative association observed could be explained by the immediate costs and organizational changes required to effectively implement live chat solutions. These technologies may not yield immediate economic benefits for certain regions, particularly those where digital infrastructure is still developing, or the regions are not specialized in sectors that use the technology and traditionally contribute to GDP.

Additionally, the utility of live chat is highly sector-specific. Regions that are predominantly driven by sectors such as manufacturing or agriculture might not see an immediate uplift in GDP from the adoption of live chat technologies. This is contrasted with service-oriented economies, where digital customer engagement plays a crucial role in economic activities.

The analysis of the relationship between GDP per capita and the adoption of web technologies, specifically Javascript libraries and Live-chat, based on Table 5 , reveals a more broad picture of how economic development influences technological adoption. This connection highlights the multifaced nature of GDP per capita and its impact on the integration of advanced digital tools.

In regions with higher GDP per capita, there is a noticeable trend towards the greater adoption of Javascript libraries. This trend can be attributed to several key factors that are inherently tied to economic prosperity. Firstly, richer regions possess the financial resources necessary for investing in new technologies. The availability of funds makes it easier for businesses and individuals to afford the costs associated with adopting and integrating complex web technologies. Secondly, these areas often boast a skilled workforce, a direct result of better access to education and professional training. Such a workforce is adept at utilizing and implementing advanced technologies, making Javascript libraries more accessible and useful. Lastly, a strong economic base supports the development of robust digital infrastructure, essential for the effective deployment and use of these technologies. High-speed internet access and modern IT infrastructure, more prevalent in economically prosperous areas, facilitate the adoption of sophisticated web technologies.

Conversely, the adoption of Live-chat technology, while influenced by GDP per capita, may not show a uniformly positive relationship across all regions. The specific utility and application of Live-chat systems play a significant role in this variance. Live-chat technology is especially beneficial in service-oriented sectors, such as retail, finance, and customer support. Therefore, regions with a strong emphasis on these industries might see a more pronounced impact of GDP growth on the adoption of Live-chat technologies. Additionally, the demand for direct customer interaction, which varies by industry and market, correlates with the economic environment. Economies with a significant digital services sector, which are often more prosperous, are likely to have a higher demand for live-chat solutions. This is further supported by the level of digital penetration within a region; economies with higher GDP per capita generally enjoy wider access to digital technologies, increasing the potential user base for Live-chat services.

Looking through the prism of the hypothesis, Hypothesis H5 posits a reciprocal relationship between technology adoption and GDP per capita, suggesting a bidirectional influence where technology adoption boosts GDP per capita, and simultaneously, regions with higher GDP per capita are more inclined to adopt new digital technologies. The evidence from the analysis supports this hypothesis, demonstrating that digital technology adoption varies with economic prosperity. For instance, technologies like Javascript libraries show a positive relationship with GDP per capita, indicating that wealthier regions tend to adopt these technologies more readily, possibly due to better resources and infrastructure. Conversely, the adoption of these technologies contributes to economic growth, as seen in the positive impacts on GDP per capita for specific technologies. Therefore, Hypothesis H5 is accepted, reflecting the intertwined relationship between economic prosperity and the embracement of new web technologies.

Despite the need for a more robust reverse causality analysis and posible application of a simultaneous equation model such as Three Stage Least Squares Methodology (3SLS) this was not possible due to the data limitations and and the scale of this study.I consider this a limitation of the study and a posibility for further research.

Table 6: The relationship between Technology Adoption and Economic Growth

	Dependent variable:									
	log(GDP/cap)									
	Ad analytics	Javascript library	Affiliate programs	Marketing automation	Audience measurement	Application performance	Live chat	CMS	Currency	Framework
Technology Adoption	-0.029	0.061***	0.099	-0.067*	0.025*	0.018	-0.119***	-0.226**	-0.037***	-0.159***
log(Population density)	-0.001	-0.002	0.001	-0.002	-0.002	-0.001	-0.002	0.002	0.004**	-0.001
Number of Firms	0.001	0.001	0.001	0.001	0.001	0.001	-0.001***	-0.001	-0.001	-0.001***
Business Sophistication	-0.079***	-0.099***	-0.073***	-0.074***	-0.076***	-0.074***	-0.074***	-0.070***	-0.078***	-0.078***
Existent Technologies	0.001	-0.001	0.001	-0.001	-0.001	-0.001*	-0.001	-0.001**	0.001	0.001
Tech. Readiness	0.005	0.020	0.005	0.015	0.015	0.014	0.005	0.013	0.016	0.002
Patent Application	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001
Quality of Infrastructure	-0.083***	-0.088***	-0.086***	-0.091***	-0.096***	-0.096***	-0.095***	-0.078***	-0.094***	-0.065***
Quality of Governance	-0.123***	-0.055	-0.128***	-0.092**	-0.080**	-0.082**	-0.076**	-0.111***	-0.079**	-0.054
log(Total Employment)	0.823***	0.797***	0.820***	0.804***	0.791***	0.789***	0.784***	0.817***	0.802***	0.683***
Talent	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.003***	-0.004***	-0.003***
Constant	0.021***	0.020***	0.021***	0.022***	0.022***	0.022***	0.025***	0.022***	0.023***	0.029***
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	No	No	No	No	No	No	No	No	No	No
Observations	1,830	1,900	1,840	1,880	1,900	1,900	1,890	1,800	1,900	1,900
R^2	0.233	0.222	0.231	0.220	0.214	0.213	0.221	0.237	0.218	0.274
Adjusted R^2	0.228	0.218	0.227	0.216	0.209	0.208	0.217	0.232	0.213	0.270
F Statistic	50.204*** (df = 11 1818)	49.104*** (df = 11; 1888)	49.972*** (df = 11 1828)	47.925** (df = 11 1868)	46.613*** (df = 11; 1888)	46.458*** (df = 11 1888)	48.566*** (df = 11 1878)	50.479*** (df = 11 1788)	47.823*** (df = 11; 1888)	64.690*** (df = 11; 1888)

Notes: The dependent variable is ' log(GDP/cap) '. Dataset corresponding to specific technology: Ad Analytics, Javascript, Affiliate Programs, Marketing Automation, Audience Measurement, Application Performance, Live Chat, CMS, Currency, and Framework. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

4 Discussion and Conclusion

4.1 Discussion

This dissertation delves into understanding the complex interactions between relatedness density, digital complexity, and technology adoption across European regions, elucidating the dynamics of digital web technology evolution and adoption and its spatial distribution in EU NUTS regions. Moreover, it looks at how place-specific factors interact with digital web technology adoption. I aimed at building the literature and empirically studying several hypotheses. First, it was expected that the relatedness density would enhance the likelihood of related entry, where firms in regions enter new digital technological domains that are closely related to their previous capabilities. My investigation provides robust support for Hypothesis H1a, showing that higher relatedness density significantly increases the odds of the entry of related web technologies. This finding emphasizes the importance of cognitive proximity and interconnected entrepreneurial ecosystems in regional innovation and technological advancement, aligning with the theoretical frameworks of evolutionary economic geography and relatedness theory. It suggests that regions characterized by a dense network of existing and new technologies characterized by higher relatedness density are more keen on navigating the intricacies of technological evolution and adopting new business models or adopting new web technologies, leveraging these connections for sustained economic growth and innovation. Besides, this should warn us regarding the weak capabilities of other regions, as they may be trapped in the incapacity to adopt new technologies without existing capabilities.

Second, Hypothesis H1b, expected a positive relationship between relatedness density and technology adoption. High relatedness density, indicating a closer relationship between existing and new technologies, is expected to facilitate technology adoption. In this case, the acceptance of Hypothesis H1b reinforces the importance of relatedness density in facilitating digital technology adoption. Regions with higher relatedness density exhibit a greater propensity for adopting new technological domains that are closely related to their existing capabilities. This highlights the need for strategic regional smart specialization policies that promote environments where knowledge and technologies can easily be interconnected and recombined. In a similar line to the Schumpeterian "New combinations". Similar to the framework proposed in this dissertation. Therefore, enhancing the firm digitalization, innovative capacity, and competitiveness of EU regions in the digital age.

For Hypothesis H2a, it was expected that Digital complexity positively influences labor productivity. In another way said, regions with higher digital complexity were hypothesized to exhibit higher productivity levels. When firms are digitized and have complex web technologies, they are expected to be more productive, therefore influencing the overall regional productivity. While, for Hypothesis H2b, it was expected a positive relationship between digital complexity and technology adoption. Higher levels of digital complexity within a region are expected to lead to greater technology adoption rates. Here it is expected a spillover effect from firms with complex technologies to other firms in a region.

However, my analysis presents a distinct picture when examining the role of digital complexity. Contrary to the expected positive relationship hypothesized in H2a by digital complexity on productivity, and in H2b by digital complexity on technology adoption, the empirical evidence reveals a more complex and sometimes inverse relationship. Higher levels of digital complexity, rather than straightforwardly translating to higher rates of technology adoption, show a paradox where regions with advanced digital ecosystems and complex technologies encounter lower rates of adoption of new digital technologies. This paradox highlights the complexities of navigating a highly developed digital environment and calls for a careful study of digital complexity's role in technology adoption. While I can suggest that when a region has more complex technologies this makes it harder for other firms to adopt them and requires higher capacities, this needs to be further investigated. This challenges the preconceived notions and underscores the potential for saturation effects and compatibility barriers, suggesting that increased digital complexity does not uniformly lead to higher digital technology adoption rates or enhanced productivity.Here I can conclude after further analysis that Hypothesis H2a is accepted, meaning that Digital complexity has a positive on productivity while H2b is not accepted, or partially accepted, as the expected positive effect of Digital complexity on web technology adoption is actually negative, leading to so the called complexity paradox.

In general, this analysis not only reaffirms the essential role of relatedness density in enhancing web technology adoption and facilitating the entry of related web technologies but also sheds light on the negative relationship between digital complexity and digital technology adoption.

The findings contribute to a deeper understanding of the factors influencing digital web technology adoption and regional development through the digitalization of smart specialization frameworks. It suggests a complex and context-dependent relationship between digital complexity, productivity, and technology adoption. This enlarges the academic discourse on path dependency and what factors inhibit digital technology adoption, and provides actionable insights for policymakers and practitioners. The dissertation one more time underscores the importance of fostering an ecosystem that nurtures innovation and leverages technological advancements for all types of firms and economic benefits, and not solely for competitive advantage.

In the next case for Hypothesis H3a, H3b, H3c where contextual factors, spatial proximity and agglomeration, have a positive effect on technology adoption. The hypothesis argues that being in an innovation-oriented context with spatial and agglomeration advantages facilitates the adoption of new web technologies.

Hypothesis 3 explores the impact of spatial proximity and agglomeration economies on web technology adoption. Technology adoption is the share of firms that adopt a specific web technology in a specific region. It states that being in a region with a developed environment and gaining from spatial and agglomeration advantages facilitates the adoption of new technologies. This enhances the understanding that clusters of interconnected firms, institutions, and industries create a dynamic entrepreneurial environment where knowledge spillover, collaboration, and innovation thrive. And when these environmental aspects are working, this accelerates the diffusion and adoption of new web technologies. Aside from that, the visible spatial autocorrelation effects as well indicate an interdependence between neighboring regions. This means that adopting a specific technology in one region will influence also the adoption in the neighboring regions. Furthermore, it was often observed in several cases a positive effect of industrial diversity (entropy) on the web technology adoption. The support for Hypothesis 3 highlights the crucial role of contextual factors in creating an ecosystem conducive to technological advancement and web technology adoption.

Moreover, the study shows how important geographical positioning is for the type of technologies to be adopted. The more integrative technologies such as the Javascript library will have smoother diffusion and will be adopted faster by firms. However, the specialized, isolated technologies (Live Chat technologies) will diffuse more slowly as they require higher adoption capacity, and it depends on the industrial specialization of the regions. So industrial specialization will eventually drive digital technologies that are adopted. Concluding that the place still matters for digital web technology adoption.

While for Hypothesis H4a, H4b, contextual factors and agglomeration effects respectively positively influence digital complexity. This suggests that the well developed entrepreneurial environment and concentration of related activities enhance a region's digital complexity.I expected a positive relationship because the regional digital complexity in itself represents an ecosystem with different actors and different fields of application.However, I reject Hypothesis 4 entirely as there was no evidence to show that local factors and human agglomeration does not influence the digital complexity of regions, or how complex a regions' web technologies are.This requires further investigation.

These hypotheses explain the complicated interplay between the place-based factors, the business environment and the dynamics of web technology adoption in EU regions. The findings suggest that the spatial factors and agglomeration characteristics of a region do not just support the development of digital complexity but also play a pivotal role in enabling web technology adoption. Therefore, refuting the idea of the death of space. This reinforces the idea that beyond the intrinsic characteristics of web technologies and the cognitive proximity between them, the spatial context and the density or geographical positioning of economic and industrial activities within a region are critical determinants of both digital complexity and the capacity for digital technological innovation and adoption.

Lastly, Hypothesis H5 expected a reciprocal positive relationship between digital technology adoption and GDP per capita. This implies that not only does technology adoption contribute to higher GDP per capita, but also that regions with higher GDP per capita are more capable of adopting new technologies.

As seen in the results, the effects of digital technology adoption on economic indicators, Hypothesis 5 investigates the complex interplay between digital technology adoption and economic growth. As seen in the results while testing Hypothesis 5 there is a reciprocal relation between technology adoption and GDP per capita, however not for all technologies. This indicates a symbiotic ecosystem dynamic where digital technological advancements contribute to economic prosperity, the relationship is significant and positive only for certain technologies

(Javascript library and Audience measurement) and negative for others. Therefore, I only partially accept the 5 hypothesis. In turn, economic prosperity creates a conducive environment for further web technology adoption for the majority of web technologies. This hypothesis is supported by empirical evidence demonstrating that regions with higher levels of economic prosperity in terms of GDP show a greater probability of adopting new technologies, such as Javascript libraries, likely due to better resources, skilled labor and the infrastructure available. This mutual influence highlights the critical role of economic conditions in shaping technology adoption patterns, highlighting that economic prosperity and technological advancements are mutually reinforcing.

Overall, Hypothesis 5 elucidates the mutual relationship between digital technology adoption and economic outcomes. It highlights the transformative power of technology in reshaping economic landscapes, driving productivity, and propelling regions towards higher levels of economic development. This discussion highlights the importance of fostering an ecosystem that encourages innovation and leverages technological adoption for economic benefit, moreover it emphasizes the bidirectional influence between technology and economic prosperity.

Finally, it is needed to integrate the insights from Hypotheses 3, 4 and 5 with the broader conceptual frameworks of entrepreneurial ecosystems and smart specialization. Here, I can extend the discussion to encapsulate how the study's findings can be integrated with the above-mentioned theoretical constructs. The dynamics of web technological innovation, adoption, and regional economic development observed in this dissertation are instrumental in understanding the entrepreneurial ecosystem and smart specialization strategy (S3).

Smart specialization recognizes the role of entrepreneurial discovery and the prioritization of innovation domains by specializing on the existent capabilities, advocating for a place-based, bottom-up approach to regional development. The findings of this study align with the S3 strategy relating to the positive impact of contextual factors on digital complexity and technology adoption (Hypotheses 2, 3 and 4). By fostering synergetic environments where entrepreneurs can leverage existing competencies and resources, regions can effectively absorb and capitalize through digital technology adoption on the opportunities presented by digital transformation. Smart specialization aims to reduce discrepancies between core and periphery regions by underlining the importance of place-specific innovation strategies that are ex-ante informed by existing local conditions and entrepreneurial activities. This can be achieved by undertaking a place-based view also on digital technology adoption.

Furthermore, the interaction between entrepreneurial ecosystems and smart specialization strategies highlights the necessity of a supportive framework for innovation and economic growth aided by digital technologies (Hypotheses 3, 4 and 5). The entrepreneurial ecosystem, with its focus on the interconnectedness of actors, resources, and institutions, provides a fertile ground for the implementation of smart specialization strategies aided by the adoption of digitally complex and related technologies. This ecosystem fosters the development of competencies and the aggregation of resources necessary for the exploration of new and related digital technological paths, as evidenced by the positive relationship between technology adoption and economic growth for specific technologies.

The study's findings highlight the importance of contextual place-based factors and the reciprocal relationship between technology adoption and GDP per capita. Moreover, the significant impact of technology adoption and density of related technologies on economic growth resonates with the core principles of smart specialization. By identifying and supporting areas of potential growth that are closely related to existing strengths, regions can achieve transformative and sustainable economic development as their new capabilities are related to their old ones. This approach not only leverages the inherent advantages of related technologies and digital complexity but also by digital technology adoption aligns with the entrepreneurial discovery processes where digital technology adoption is transformed into new business models and spinoffs, that are central to the entrepreneurial ecosystem and smart specialization framework.

In summary, this dissertation attempts to integrate entrepreneurial ecosystems and smart specialization strategies with Economic Geography aspects and digitalization. Within the study, I highlight the complex interdependencies between related and complex digital technologies, digital technology adoption, economic growth, and regional innovation policies. All these previously enumerated findings ask for a detailed understanding of regional development, where the synergies between digital technological advancements, economic and business conditions, and policy frameworks with a place-based focus are recognized and improved to foster sustainable growth and digital innovation across European regions.

4.2 Implications for Policy and Practice

The strategic implications of this dissertation for policymakers and stakeholders are significant, particularly when digitalization is viewed through the lenses of space, geography, smart specialization (S3), and entrepreneurial ecosystems. The significance of relatedness density in enhancing digital technology adoption and digital complexity presents a compelling case for the development of interconnected technological ecosystems. These findings highlight the importance of using spatial and geographic advantages in regional development policies to foster environments that support the integration of new technologies. Policymakers are encouraged to recognize the spatial dimensions of digitalization and innovation, ensuring that regional policies capitalize on each region's unique geographic characteristics and existing digital technological capabilities or industrial orientation.

The concept of smart specialization can serve as a key framework for achieving the upper objectives. It advocates for policies that promote innovation and inclusive sustainable growth by focusing on the existing unique regional strengths, capabilities, and competitive advantages. Smart Specialization can take a similar view on digitalization. As its approach aligns with the need to foster environments that leverage existing digital technological capabilities, diversity of industries and knowledge networks, enabling regions to effectively integrate new digital technologies and maintain their competitiveness in the digital era. Policymakers should embrace the principles of smart specialization to guide the strategic prioritization and development of regional entrepreneurial ecosystems, emphasizing the importance of entrepreneurial discovery and innovation-driven economic development in digitalization.

Moreover, the digital complexity paradox identified in this study highlights the challenges of digital technology saturation, the complexity of adoption and compatibility issues, necessitating a balanced approach to digital advancement. By following the smart specialization strategy, policymakers should focus on optimizing existing technological infrastructures while carefully integrating new digital innovations. This requires considering attention to understanding digital complexity's role in technology adoption, emphasizing the need for policies that support sustainable technological advancement and economic growth within the context of each region's unique spatial and geographic characteristics.

By integrating the concepts of smart specialization, entrepreneurial ecosystems and digital technology adoption into regional development strategies, policymakers can create a supportive environment for innovation and further technology adoption or new business models. This environment will encourage collaboration among stakeholders, leverage the region's unique spatial and geographic advantages, and focus on building and strengthening the interconnected digital-physical technological ecosystems that are crucial for the digital era. Thus, crafting policies that reflect an understanding of the spatial dynamics of innovation, the principles of smart specialization, and the importance of entrepreneurial ecosystems becomes essential for fostering technology adoption, digitalization, and overall regional economic growth.

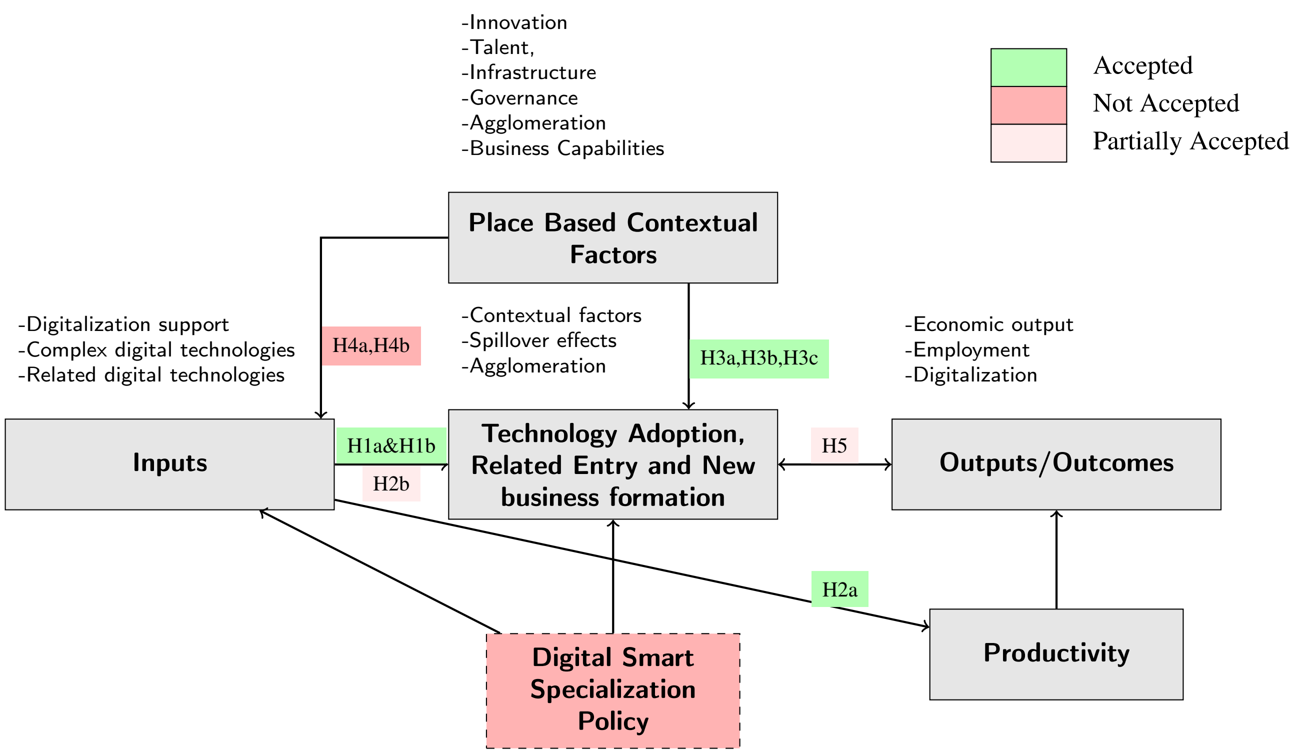

Figure 4: Results of the hypothesis testing

4.3 Limitations and Directions for future research

This dissertation can serve as the cornerstone for numerous directions of future research. A limitation of this thesis is in the sample of firms used for analysis. While Crunchbase is an exciting database, its focus on highly technological-high growth firms might exclude a relevant number of firms that were overlooked by the Crunchbase algorithms. Another aspect that requires attention is that this work used Digital Complexity as a proxy for digitalization of regions. While complexity is a good measurement of novel knowledge and capability, it might exclude those regions that do not have high-growth businesses or those that lack complex technologies. Applying fixed effects in the panel model often changed the sign of the result parameter, this indicated data limitations or limitations of the empirical strategy. One critical area that requires attention involves understanding the mechanisms through which regional digital complexity might negatively impact technology adoption but also productivity. Moreover, future studies should explore the effects of market saturation of digital technology, compatibility issues, and the incremental costs associated with the adoption of new digital web technologies, especially in regions with advanced digital ecosystems. In this study I focused more on the impact of related technologies and, therefore on incremental innovations, a deeper focus on unrelated web technologies is required. Additionally, there is a need for comparative studies across different geographic contexts to unravel the spatial dynamics of technology adoption and digital complexity. While this empirical study attempted to examine the place-specific factors, more attention should be paid to digital infrastructure and digital adoption capacities, as few digitalization controls were considered. Such research could elucidate our understanding of how different regions navigate the challenges and opportunities of digital transformation. To diminish the gap between developed and underdeveloped regions in their capacity to digitalize, policy interventions are necessary, and this dissertation offers valuable insights for both policymakers and practitioners, but more specific case studies are needed. Finally, there's a need for a more robust framework for testing the relationship between web technology adoption and economic growth. A reverse causality analysis and possible application of a simultaneous equation model such as Three Stage Least Squares Methodology (3SLS) was not possible due to the data limitations and the scale of this study.

4.4 Conclusion

In conclusion, this dissertation has illuminated the intertwined relationships between relatedness density, digital complexity, and technology adoption across European regions. By exploring these dynamics, the study contributes to a deeper understanding of the factors that drive digital technological evolution and regional development. The findings underscore the importance of fostering interconnected innovation and entrepreneurial ecosystems and adopting a direct and clear approach to digital complexity. As we move forward, it is imperative that policymakers and stakeholders heed these insights, leveraging them to foster environments that support innovation, economic growth, and technological advancement. This study designed a framework and identified specific factors influencing digital technology adoption. Future research in this domain holds the potential to further refine our understanding of these complex dynamics, offering guidance for navigating the challenges of the digital era.

This comprehensive exploration not only advances the academic discourse on digital transformation but also provides actionable recommendations for policymakers and practitioners aiming to harness the benefits of digital technological advancements for regional development.

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CONFERENCE PRESENTATIONS

1. Name of the conference: The 6th Geography of Innovation Conference 2022

   When: 4-6 July 2022

   Where: Milan

   Title of the presentation: More Than Machinery, We Need Humanity - The Importance of a Humanised Governance Quality Measurement for Regional Innovation and Smart Specialisation Policies

2. Name of the conference: 20th Annual Meeting, Space and State

   When: 6-7 October 2022

   Where: University of Public Service, Budapest, Hungary

   Who: Stefan Apostol, PhD candidate, University of Pécs – Zoltán Gál, senior research fellow, CERS Institute for Regional Studies

   Title of the presentation: Role of Foreign Direct Investment in regional economic growth and regional productivity – the case of CEE countries (online presentation)

3. Name of the conference: DRUID23 Innovation Conference

   When: June 10-June 12, 2023

   Where: NOVA School of Business and Economics, Portugal

   Who: Stefan Apostol, PhD candidate

   Title of the presentation: "Digitalisation in European regions: relatedness, economic complexity, and productivity" (poster presentation)

4. Name of the conference: ERSA 2023 Conference in Alicante

   When: 29 August - September 1st, 2023

   Where: University of Alicante, Spain

   Who: Stefan Apostol, PhD candidate, László Szerb, Richárd Farkas, University of Pécs

   Title of the presentation: The Regional Diffusion of Web Technologies in Europe: Is there a digital diffusion divide?