The Innovation of the Production System in the Italian Regions

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Abstract

In this article I analysed the trend of innovation in the production system in the Italian regions using ISTAT-BES data. After presenting a static analysis and innovation trends of the production system, I present a clustering with a k-Means algorithm optimized with the Silhouette coefficient. Subsequently, an econometric analysis is presented for estimating the determinants of innovation in production systems. Finally, the results are critically discussed with economic policy recommendations.

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

Keywords: Innovation, Innovation and Invention, Management of Technological Innovation and R&D, Technological Change, Intellectual Property and Intellectual Capital

1. Introduction

The relationship between innovation and productivity in firms across Italian regions represents a dynamic interplay that significantly influences economic growth and regional development. Italy, with its diverse economic landscapes ranging from the industrialized North to the more agrarian South, provides a fascinating context for examining how innovation drives productivity at the firm level within different regional settings. At the heart of this relationship is the concept that innovation—whether in the form of new products, processes, or business models—acts as a catalyst for improving firm productivity, which in turn, contributes to the overall economic performance of a region. The capacity for innovation varies significantly across Italian regions due to differences in industrial specialization, the presence of research and development (R&D) infrastructure, access to capital, and the availability of skilled labor. For instance, regions such as Lombardy and Emilia-Romagna have traditionally demonstrated strong manufacturing sectors supported by robust innovation ecosystems, leading to higher productivity levels in firms located within these areas. Moreover, the role of small and medium-sized enterprises (SMEs), which form the backbone of the Italian economy, is crucial in understanding the innovation-productivity nexus. These firms often face unique challenges and opportunities in adopting innovative practices, influenced by regional policies, the local business environment, and networks that facilitate knowledge transfer and collaboration. Understanding the relationship between innovation and productivity in Italian firms necessitates examining the interplay between various factors, including governmental policies aimed at fostering innovation, the role of technological districts and clusters, and the influence of international

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competition and globalization. Such an analysis not only sheds light on the mechanisms through which innovation enhances productivity but also highlights the importance of tailoring policies to the specific needs and strengths of each region to maximize economic growth and competitiveness.

The article continues as follows, in the second section I analyze the reference literature, in the third section I analyze the data relating to the trend of innovation of production systems in the Italian regions, in the fourth chapter I present a clustering, in the fifth section I present the model econometric, the sixth chapter presents the policy implications, the seventh chapter concludes.

2) Literature Review

Acs et al., (2009) explores how knowledge generated within organizations can overflow, creating opportunities for individuals to establish new ventures. By integrating theoretical insights with empirical evidence, the study illustrates that areas with rich knowledge resources witness higher entrepreneurial activity. This underscores the importance of fostering environments that facilitate knowledge transfer and reduce barriers to entrepreneurship to spur economic growth and innovation. Arora & Athreye, (2012) investigates the role of patent systems in motivating firms to invest in R&D by analyzing the returns firms obtain from patenting. The research reveals that while patents serve as incentives for R&D investments, their effectiveness varies across different sectors and companies. This variation calls for a nuanced approach to patent policy to ensure it effectively encourages innovation while maintaining competitive markets and access to knowledge. Arora, Athreye, & Huang, (2016) revisits the open innovation paradigm, particularly examining how it intersects with the practice of patenting in the UK. By evaluating the dynamics between collaborative innovation efforts and intellectual property strategies, the article highlights a complex relationship where openness in innovation processes coexists with strategic patenting to protect competitive advantages. This duality indicates that firms can navigate the paradox of openness by balancing collaborative innovation with protective measures to sustain their innovative capabilities and market position. Audretsch & Feldman, (1996) delves into how the geographic distribution of R&D activities influences innovation and production. The analysis demonstrates that innovation is geographically concentrated due to the spillover effects of R&D, suggesting that physical proximity plays a crucial role in the diffusion of knowledge and the clustering of innovative activities. This finding has significant implications for regional economic development policies, highlighting the need to support innovation ecosystems to capitalize on R&D spillovers and enhance regional competitiveness.

In their 2014 study, Audretsch, Coad, and Segarra probe the nexus between firm growth and innovation, unraveling how innovation acts as a catalyst for the expansion and success of small and medium-sized enterprises (SMEs). This work emphasizes the disproportionate benefits that SMEs can reap from innovation activities, given their unique agility and the significant impact innovation can have on their market positioning and competitive edge. The study not only underscores the pivotal role of innovation in SME growth but also suggests the broader economic implications of fostering an environment conducive to innovative endeavors. Further dissecting the fabric of innovation, Audretsch and Belitski's 2019 investigation into the UK's innovative industries brings to the fore the complexities of collaborative innovation. Their findings illuminate the nuanced reality that while collaboration is generally seen as beneficial to innovation, there are limits to its effectiveness. The research indicates that there are diminishing returns to collaboration and that not all partnerships yield the expected synergistic benefits. This work serves as a critical reminder of the importance of strategic selection and management of collaborative ventures to optimize innovation outcomes. Balland, Boschma, and Frenken (2015) delve into the concept of proximity and its relationship with

innovation, moving the discussion from static analyses to dynamic interpretations. Their comprehensive study reveals how different forms of proximity—whether geographical, cognitive, or social—play varying roles at different stages of the innovation process. This dynamic perspective on proximity and innovation underscores the evolving nature of innovation ecosystems and the need for policies and business strategies that adapt to these changing dynamics. The research by Beers and Zand (2014) further expands on the theme of collaboration, focusing on the diversity of R&D partnership networks. Their empirical analysis highlights the positive impact of partner diversity on a firm's innovation performance, suggesting that a wide array of perspectives and expertise can enrich the innovation process. This finding is particularly relevant in the context of globalized research and development activities, where cross-disciplinary and cross-border collaborations have become increasingly common. Bartelsman, Falk, Hagsten, and Polder's 2019 study connects technological infrastructure, specifically broadband connectivity, with firm-level productivity and innovation. By providing firm-level evidence from ten European countries, the researchers demonstrate the foundational role of digital infrastructure in facilitating innovative activities and improving operational efficiency. Their work adds an important dimension to the innovation discourse, highlighting the critical importance of digital connectivity in today's economy. Lastly, Belitski, Caiazza, and Lehmann (2019) address the evolving landscape of entrepreneurship research, advocating for the exploration of new frontiers and the breaking of boundaries within this domain. Their call for interdisciplinary research approaches to tackle complex entrepreneurial challenges emphasizes the necessity of continuous innovation not only in business practices but also in academic inquiry.

Denicolai, Ramirez, and Tidd's 2016 study provides a critical examination of the traditional dichotomy between internal R&D efforts and external knowledge acquisition. By focusing on the concept of absorptive capacity, they argue that a firm's ability to innovate over time is significantly influenced by its capacity to assimilate and apply external knowledge. This dynamic perspective on absorptive capacity challenges firms to rethink their innovation strategies, emphasizing the importance of a balanced approach that leverages both internal and external sources of knowledge to drive innovation. In his 2004 paper, Duguet delves into the nuanced relationship between public R&D subsidies and private R&D investment. Through econometric analysis at the firm level, the study seeks to unravel whether government incentives serve as a complement to or a substitute for privately funded R&D. The findings of this analysis bear significant implications for policy design, suggesting that the interplay between public support and private investment is complex and contingent on various factors. This research underlines the necessity for carefully crafted policies that effectively encourage private R&D investment without inadvertently discouraging it. The UK Innovation Survey, conducted by the Department of Enterprise, Trade, and Investment in 2018, offers a comprehensive dataset that spans over two decades of innovation activities within the UK. This extensive dataset allows researchers and policymakers to trace the evolution of innovation practices and outcomes across different sectors, providing valuable insights into the drivers and barriers of innovation within the UK economy. The longitudinal nature of this data collection is instrumental in understanding how innovation dynamics have shifted over time and the impact of these changes on economic performance. Gibbons and Murphy's 1990 study on relative performance evaluation for chief executive officers investigates how performance-based evaluation mechanisms influence CEO behavior and company outcomes. By analyzing the effectiveness of these evaluation systems, the paper sheds light on the intricate dynamics of executive motivation and its consequences for organizational performance. This research has broader implications for corporate governance and the design of incentive structures that align the interests of executives with those of the company and its stakeholders. Giovannetti and Piga's 2017 research on the contrasting effects of active and passive

cooperation within British local innovation networks addresses how different forms of collaboration impact innovation and productivity. The study distinguishes between active cooperation, where firms engage in joint innovation efforts, and passive cooperation, characterized by less intensive forms of collaboration. The findings highlight the significance of strategic, active collaborations in enhancing innovation outcomes, suggesting that not all forms of cooperation are equally beneficial. Griliches' seminal 1979 work tackles the methodological challenges associated with assessing the contribution of R&D to productivity growth. By questioning the approaches used to measure the impact of innovation on economic performance, Griliches highlights the complexity of quantifying the benefits of R&D investments. This research underscores the ongoing challenges in innovation economics and the need for robust methodologies that accurately capture the nuances of innovation's contribution to growth.

Haltiwanger, Jarmin, and Miranda (2013) break new ground in the job creation discourse by demonstrating that the age of firms, rather than just their size, plays a crucial role in job creation, with young firms being particularly significant contributors. This finding challenges conventional wisdom and suggests that policies aimed at supporting entrepreneurship and the nurturing of young firms could be key to stimulating job growth. Helpman and Grossman (1991) contribute to the theoretical underpinnings of how innovation fuels global economic expansion, proposing that technological innovation and the cross-border diffusion of knowledge are central to economic development. Their work lays a foundation for understanding the global innovation ecosystem and the importance of open, collaborative environments that facilitate knowledge exchange. Hsieh et al. (2018) provide empirical evidence on how both foreign and domestic collaborations enhance the novelty of product innovations and drive firm growth, underlining the importance of diverse partnerships in fostering innovative outcomes. This insight is critical for firms looking to innovate and expand, suggesting that a strategic approach to collaboration can significantly amplify innovation performance. Kaiser (2002) tackles the methodological challenges in measuring knowledge spillovers, highlighting the difficulties in capturing the indirect benefits of innovation. This analysis is crucial for policymakers and researchers aiming to assess the impact of innovation activities and to design policies that encourage beneficial spillovers. Knott, Posen, and Wu (2009) delve into the nuanced nature of spillover effects, emphasizing that the gains from external knowledge are not uniformly distributed across firms, which has profound implications for competitive strategies and industry evolution. Their work sheds light on the strategic management of knowledge flows within and between firms. Kugler (2006) examines the industry-specific effects of foreign direct investment (FDI) on knowledge spillovers, questioning whether these benefits are contained within industries or have a broader economic impact. This study contributes to the debate on the role of FDI in host economies, suggesting a more complex interplay between foreign investment and local industry development. Lach (2000) and Lach and Sauer (2002) explore the effects of R&D subsidies, with findings that indicate both stimulating and displacing effects on private R&D investment and the productivity enhancements associated with such subsidies.

Roper, Love, and Bonner (2017) delve into the critical role of local knowledge externalities and firms' strategic knowledge-seeking behaviors in driving innovation performance. Their work highlights the significance of geographical proximity to knowledge hubs and the active engagement of firms in tapping into these resources as pivotal for enhancing innovation outputs. This suggests that the innovation capacity of firms is not solely an internal matter but is profoundly influenced by the richness of the local ecosystem and the firm's ability to engage with it. Rosenbusch, Brinckmann, and Bausch (2011) challenge the conventional wisdom that innovation is invariably beneficial for SMEs. Through a meticulous meta-analysis, they reveal a more nuanced relationship between innovation

and performance, suggesting that factors such as market dynamics, the nature of the innovation, and the firm's internal capabilities significantly influence this relationship. This nuanced understanding underscores the complexity of innovation processes and the variable outcomes they produce, particularly within the SME sector. Scherer (1982) examines the flow of technology across industries and its implications for productivity growth. His analysis illuminates how cross-sectoral transfers of knowledge and technology can spur innovation, underscoring the interconnectedness of different sectors and the importance of a permeable knowledge economy that facilitates such flows. This perspective not only broadens the understanding of sources of innovation but also highlights the systemic nature of economic growth. Stojčić, Srhoj, and Coad (2020) offer an evaluation of innovation procurement policies across several Central and Eastern European countries, viewing these policies as mechanisms for building innovative capabilities. Their study sheds light on the efficacy of policy interventions in fostering innovation and suggests significant variations in outcomes across different national contexts. This research points to the critical role of governmental policies in shaping the innovation landscape and the need for tailored approaches that consider local conditions and capabilities. Syverson (2011) tackles the broad question of productivity determinants, presenting a comprehensive overview of factors ranging from technological advancements to organizational practices and market structures. His work emphasizes the multifaceted nature of productivity and the various levers that can influence it, providing a foundation for both theoretical and practical considerations in the pursuit of economic efficiency. Tomlinson and Jackson (2013) investigate the impact of cooperative ties and external factors on innovation within an industrial district, providing insights into how localized networks and the external environment can support or hinder innovation. Their findings highlight the importance of collaboration and the influence of external market and regulatory conditions on the innovation process, offering valuable lessons for firms operating within tightly knit industrial clusters. Lastly, Van Ark, Inklaar, and McGuckin (2003) explore the transition towards a new digital economy, focusing on productivity, ICT, and the service industries in Europe and the United States. Their analysis of the differential impacts of ICT adoption on productivity across sectors and regions underscores the transformative potential of digital technologies and the varying pace of this transformation across different economic contexts.

3) Ranking of Italian Regions and Macro-regions

In 2020, an examination of the innovation levels within the production systems of Italian regions revealed a diverse landscape. The Marche region emerged as the most innovative, scoring the highest with 59, closely followed by Piedmont at 58.3. This high level of innovativeness likely stems from robust research and development policies, strong industry-university collaborations, and a significant number of high-tech firms. In the high-medium range, regions like Umbria (51.6), Abruzzo (51.9), Friuli-Venezia Giulia (52.2), Emilia-Romagna (52), and Veneto (52.3) displayed substantial innovation capabilities, suggesting they benefit from good infrastructure, a skilled workforce, and investment in R&D. Lombardy (46.5), Trentino-Alto Adige (46.7), and Lazio (46.6) were positioned in the middle range, indicating moderate innovation scores despite their economic significance, pointing towards potential areas for enhancing innovation policies and support. Regions such as Calabria (47.8), Puglia (48.2), and Campania (48.3) were identified as emerging, with their scores reflecting an increasing focus on developing innovative ecosystems through technological investment and education. Conversely, Valle d'Aosta (35.3) and Molise (34.2) had the lowest scores, attributed to factors like limited industrial bases, smaller size, or less emphasis on innovation-driven industries, highlighting areas for possible intervention to boost innovation. The southern regions, including Sicily and Sardinia with scores around 40, typically scored lower than their northern and central

counterparts, underscoring historical challenges like infrastructure and innovation investment. However, the emerging innovation in regions like Calabria and Puglia indicates growth potential. This data underscores the varied innovation landscape across Italy, spotlighting regions leading in innovation and those with emerging growth potential, suggesting that efforts to stimulate innovation could involve enhancing digital infrastructure, promoting industry-academia collaboration, and boosting R&D investments, tailored to the unique needs and strengths of each region (Figure 1).

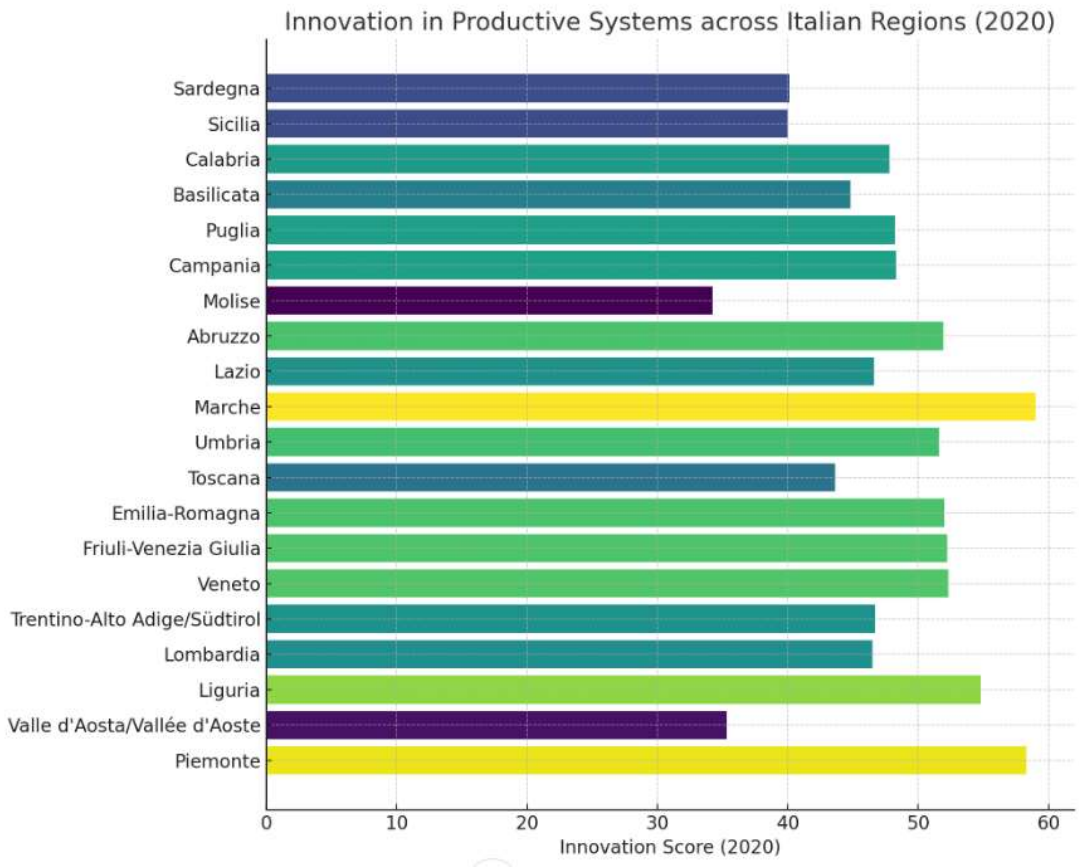

Figure 1. The Innovation of the Production System among Italian regions.

The data shows the innovation of the production system in the different Italian regions, comparing the years 2004 and 2020 and highlights the following predominant trends. Calabria, Marche, and Abruzzo stand out for having recorded the highest percentage increases, of 30.2%, 29.4%, and 21.5% respectively. This suggests considerable progress in the innovation of the production system in these regions. Liguria and Puglia also show significant improvements, with percentage increases of 22.3% and 22.0% respectively. Valle d'Aosta and Trentino-Alto Adige recorded the steepest percentage decreases, of -29.3% and -15.2% respectively, indicating a significant decline in innovation. Even Lombardy, which is one of the most productive regions in Italy, saw a decrease of 10.6%. Some regions such as Emilia-Romagna, Tuscany, Umbria, and Veneto showed relatively low percentage variations, suggesting a certain stability in the level of innovation of the production system. Piedmont is the only region that shows an absolute increase of more than 5 percentage points while maintaining a percentage increase below 10%, indicating constant but moderate growth. It is interesting to note how the regions of Southern Italy, traditionally considered less innovative than the North, have recorded significant percentage increases, suggesting potential changes in the geographical

distribution of innovation within the country. These data reflect the complex and variable dynamics of innovation in the Italian production system, influenced by economic, social, and political factors. The significant progress in some regions of the South highlights the ability of these areas to develop and adopt innovations, potentially narrowing the historical gap with the North. However, the decline in innovation in key regions such as Lombardy and Trentino-Alto Adige raises important questions about the challenges these areas are facing (Figure 2).

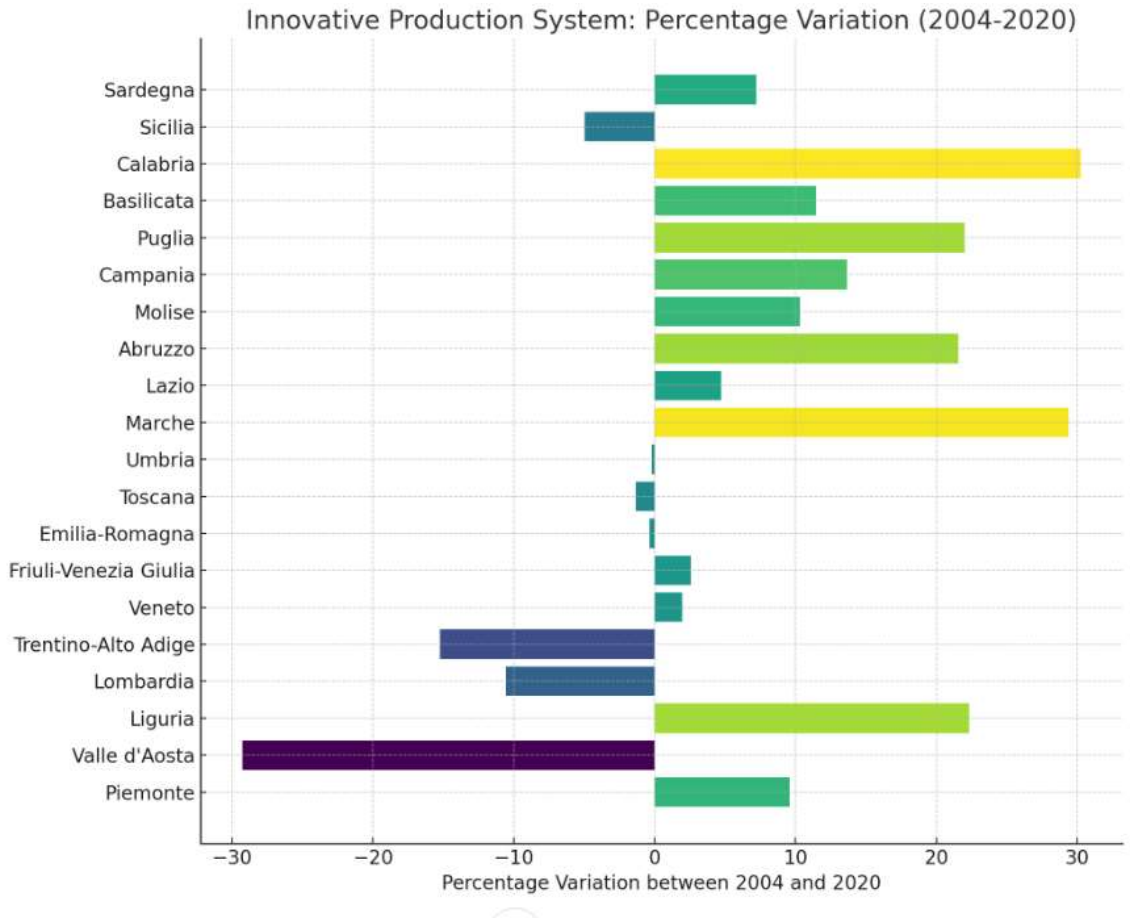

Figure 2. Percentage variation of innovative production system between 2004 and 2020.

The data presented offers a synthetic look at the evolution of innovation in the macro-geographical areas of Italy - North, Central and South - between 2004 and 2020, through the absolute change and the percentage change. This analysis helps to understand how innovation dynamics have developed in relation to the different socio-economic and territorial contexts of the country. Northern Italy shows a moderate increase in innovation, with an absolute change of +1.7 and a percentage change of 3.28%. This suggests growth in innovation, albeit at a slower pace than other areas. Being traditionally the economic locomotive of the country, with an already advanced industrial and technological fabric, for the North this increase represents a further evolution on an already solid base, perhaps reflecting greater challenges in increasing innovation percentages on high starting levels. Central Italy records growth in innovation with an absolute variation of +2.7 and a percentage of 5.97%. This increase, higher than that of the North, may indicate an acceleration in the development of innovative policies and projects that have found fertile ground in this macro-area, perhaps also thanks to a dynamic entrepreneurial environment and a strong presence of universities and research centers that promote innovation. Southern Italy shows the most significant increase, with an absolute variation of +5.4 and a percentage of 13.27%. This notable leap can be interpreted as the result of an intense recovery

activity and investment in innovation, in an area that has historically recorded structural delays compared to the rest of the country. This growth could reflect the success of policies aimed at innovation, the attraction of investments, the promotion of startups and the improvement of infrastructure, as well as the impact of European funds aimed at cohesion and regional development. The percentage change shows a clear trend: the South is catching up in terms of innovation at a faster pace than the Center and the North. This phenomenon, known as the convergence process, is crucial for reducing the economic and production gap between the different areas of the country. The more marked increase in the South suggests a vitality that could significantly change the Italian economic and productive landscape, leading to a greater balance between the geographical areas. However, it is important to consider that high growth percentages are more easily achieved starting from lower bases, as in the case of the South compared to the North. In conclusion, these data reflect the complexity and heterogeneity of innovation development in Italy, highlighting both the challenges and opportunities for the country's economic future. The significant growth in the South opens up optimistic reflections, but also underlines the need for continuous and targeted policies to support and promote innovation in all Italian regions (Figure 3).

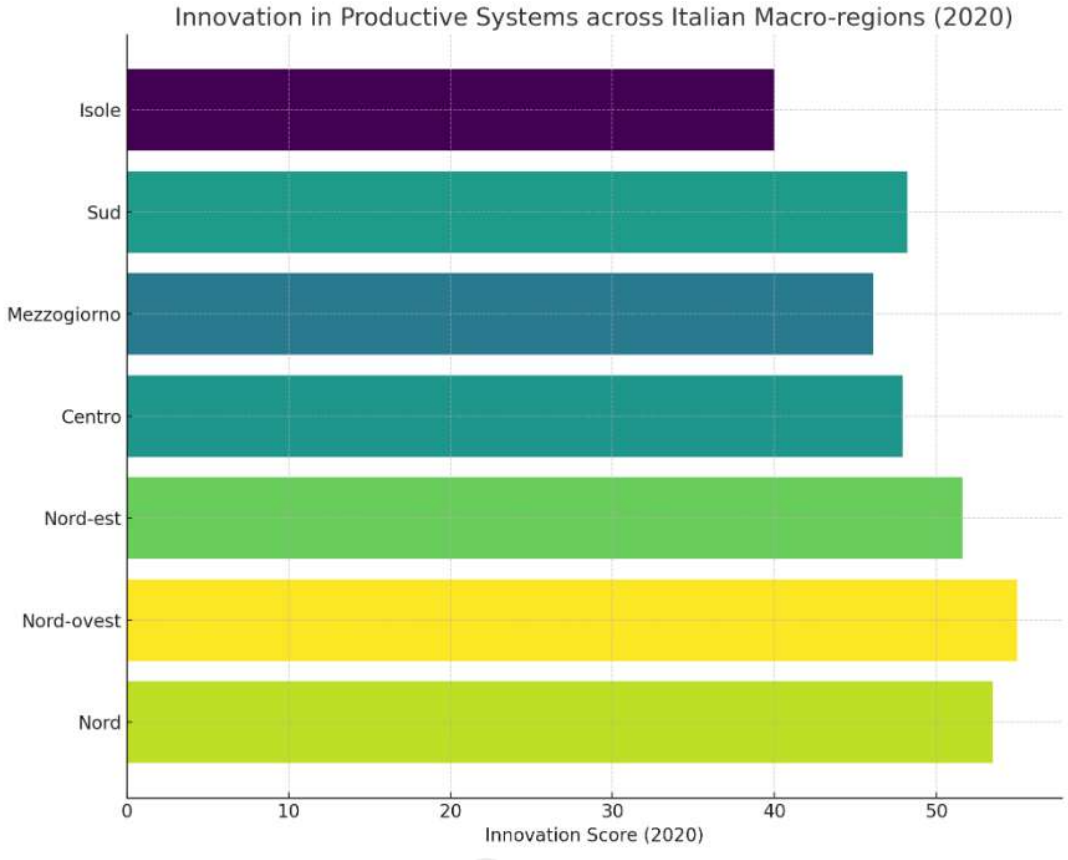

Figure 3. Innovative Production System across Italian macro-regions in 2020.

4) Clusterization with k-Means Algorithm Optimized with the Silhouette Coefficient

The optimal number of clusters for the data on innovative production systems across Italian regions, determined using the Silhouette coefficient, is 2, with a Silhouette score of approximately 0.366. This suggests that, based on the given data from 2004 to 2020, the regions can be effectively grouped into two clusters to maximize within-cluster similarity and between-cluster differences. The graph now

includes labels for each region, showing how they are distributed across the two clusters based on their innovation scores from 2004 to 2020 (Figure 4).

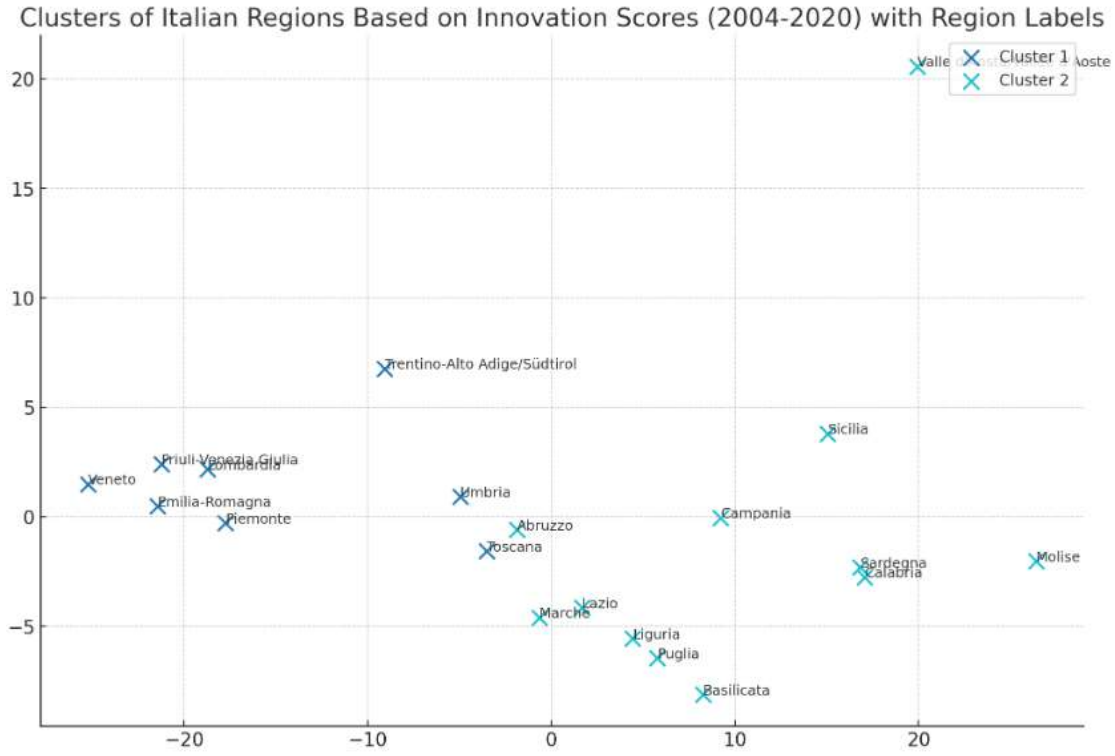

Figure 4. Clusterization of the italian regions with k-Means algorithm optimized with Silhouette Coefficient.

Cluster 1 contains regions that might be characterized by higher innovation scores or specific patterns of innovation growth over the period. These include: Piemonte, Lombardia, Trentino-Alto Adige/Südtirol, Veneto, Friuli-Venezia Giulia, Emilia-Romagna, Toscana, Umbria. Cluster 2 comprises regions that could have experienced different patterns of innovation change, possibly lower scores or more fluctuation. These regions are: Valle d'Aosta/Vallée d'Aoste, Liguria, Marche, Lazio, Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, Sicilia, Sardegna

This clustering provides insights into the innovation dynamics at a regional level in Italy. Cluster 1 might be indicative of regions with robust or improving innovation systems, likely due to stronger industrial bases, better infrastructure for innovation, or more significant investment in research and development. Cluster 2 reflects a different scenario, perhaps regions with challenges in maintaining or enhancing their innovation capabilities, which might be influenced by economic disparities, lesser focus on innovation and technology, or infrastructural challenges. The clustering of Italian regions into two distinct groups, with northern regions predominantly in Cluster 1 and southern regions entirely in Cluster 2, underscores a well-documented socio-economic divide in Italy, often referred to as the North-South divide. This divide is characterized by various economic, social, and cultural disparities that have historical roots and have persisted over time. Northern Italy, represented in Cluster 1, is known for its robust industrial economy, higher GDP per capita, and greater investment in research and development. The regions in this cluster, including Lombardia, Veneto, Emilia-Romagna, and others, are among the most economically developed in Italy. They host a significant portion of the country's manufacturing and service industries, benefit from a more developed infrastructure, and generally have higher standards of living. These factors contribute to stronger

innovation systems, as evidenced by the higher innovation scores over the period studied. In contrast, Cluster 2 includes all southern regions, reflecting the challenges these areas face in terms of economic development and innovation. Southern Italy, or the Mezzogiorno, traditionally has a weaker economy, with higher unemployment rates, lower GDP per capita, and less industrialization compared to the north. These regions have historically been more rural and agrarian, with a slower pace of economic development and innovation. The clustering suggests that these socio-economic challenges have a direct impact on the regions' ability to innovate and develop productive systems. The clustering of Italian regions according to innovation scores, aligning with the North-South divide, highlights the importance of tailored regional development policies. To address the disparity, there is a need for targeted investment in the south to enhance infrastructure, education, and access to technology, aiming to foster innovation and economic growth. Additionally, the success factors in northern regions provide valuable lessons that could be adapted and applied in the southern context, potentially through policy initiatives focused on innovation, technology transfer, and entrepreneurship. In conclusion, this analysis not only reflects existing socio-economic divisions but also emphasizes the role of innovation as both a driver and an indicator of regional development. Addressing the innovation gap between the north and south could be pivotal in achieving more balanced economic growth across Italy.

5) The Econometric Model

An econometric estimate of the innovation of the production system in the Italian regions. Below I present an econometric analysis for estimating the innovation of the production system in the Italian regions. The data refers to the 20 Italian regions between 2004 and 2022. The analyzes were carried out using the following models: Panel Data with Fixed Effects, Panel Data with Variable Effects, Pooled OLS, Dynamic Panel. I have used the abbreviations as indicated in the Table 1.

Estimation of the Innovation of the Production System				
	Variable	**Acronym**	**Relation**	**Label**
y	Innovation of the production system	IPS		A99
x_s	Search intensity	SI	positive	A97
	Propensity to patent	PTP	negativa	A98
	Regular internet users	RIU	positive	A103
	Availability of at least one computer and Internet connection in the family	AOC	negative	A104
	Municipalities with entirely online services for families	MEOS	positive	A105

Table 1. Abbreviations and Labels.

I present the statistical results in table 2.

Fixed-effects					
		Coefficient	*Std. Error*	*p-value*	
Const		21.4228	5.05661	<0.0001	***
A97	SI	25.0734	3.52344	<0.0001	***
A98	PTP	−0.127425	0.0423299	0.0028	***
A103	RIU	0.755733	0.253734	0.0031	***
A104	AOC	−1.10394	0.278894	<0.0001	***
A105	MEOS	0.793068	0.177675	<0.0001	***
Random-effects					
		Coefficient	*Std. Error*	*p-value*	
Const		21.2845	4.79939	<0.0001	***
A97	SI	20.6969	3.13878	<0.0001	***

A98	PTP	−0.0866883	0.0322623	0.0072	***
A103	RIU	0.693416	0.235690	0.0033	***
A104	AOC	−1.00740	0.263338	0.0001	***
A105	MEOS	0.817408	0.172934	<0.0001	***
Random-effects					
		Coefficient	*Std. Error*	*p-value*	
A99(-1)	IPS	−0.713375	0.00939171	<0.0001	***
A97	SI	19.0252	1.96745	<0.0001	***
A98	PTP	−0.0742485	0.0314450	0.0182	**
A103	RIU	−1.08174	0.250660	<0.0001	***
A104	AOC	1.84450	0.323645	<0.0001	***
A105	MEOS	0.295478	0.0444530	<0.0001	***
Pooled OLS					
		Coefficient	*Std. Error*	*p-value*	
const		21.7579	4.19768	<0.0001	***
A97	SI	15.0889	2.68568	<0.0001	***
A98	PTP	−0.0478450	0.0245332	0.0519	*
A103	RIU	0.558932	0.224242	0.0131	**
A104	AOC	−0.831608	0.252295	0.0011	***
A105	MEOS	0.855859	0.173267	<0.0001	***

Table 2. Statistical Results

In particular I have estimated the following equation:

$$\boldsymbol{IPS_{it} = \alpha + \beta_1 (SI)_{it} + \beta_2 (PTP)_{it} + \beta_3 (RIU)_{it} + \beta_4 (AOC)_{it} + \beta_5 (MEOS)_{it}}$$

with i=20 and t=[2004;2022].

There is a positive relationship between the value of IPS and the value of the following variables, namely:

- SI: the positive relationship between IPS and SI is a fundamental concept in the knowledge economy and represents a pillar for the economic and competitive development of a country or region. This correlation highlights how investments in research and development (R&D) are crucial to stimulate innovation within production systems, leading to a virtuous circle of growth and technological renewal. Investments in research foster a stimulating environment for scientists, engineers and technicians, promoting creativity and the ideation of new solutions and technologies. High research intensity can accelerate new product development cycles, allowing companies to respond more promptly to market needs and competitive dynamics. Productive innovation, fueled by solid research activities, improves the competitiveness of companies on national and international markets, through the offering of distinctive products or services. Research-driven innovation contributes to sustainable economic growth, generating new business opportunities, skilled jobs and improving the trade balance. Regions with high levels of R&D investment tend to experience higher rates of innovation and more robust economic growth. This relationship is particularly evident in high-tech sectors, such as pharmaceuticals, biotechnology, ICT and advanced manufacturing, where research plays a crucial role in the development of new products and services. The positive relationship between innovation of the production system and research intensity underlines the importance of investments in R&D as a lever for innovation and economic growth. Public policies aimed at supporting scientific and technological research, together with incentives for companies investing in innovation, are fundamental to fully exploit the potential of this dynamic relationship.
- RIU: the positive relationship between IPS and RIU reflects how the widespread adoption of digital technologies and access to the Internet are catalysts for innovation within production

systems. This correlation underlines the importance of a digitally connected society in promoting technological evolution and continuous improvement of production processes, products and services. The widespread presence of Internet users makes it easier for companies to gather real-time feedback, allowing them to innovate in a more targeted and efficient way. Online platforms and social media offer businesses valuable tools to understand consumer needs and preferences, guiding the development of new products and services. The high penetration of the Internet stimulates companies to digitize their production processes, improving operational efficiency through automation, data analysis and predictive maintenance. This shift to intelligent manufacturing, or Industry 4.0, is a fundamental aspect of innovation in the production system. Regular Internet users have access to a vast reservoir of knowledge, educational resources, and professional networks. This knowledge-friendly environment supports open innovation, enabling businesses to collaborate across traditional boundaries and accelerate technological development. The spread of the Internet promotes the creation of dynamic startup ecosystems, where entrepreneurs and innovators can easily share ideas, access capital and experiment with new business models. These ecosystems are often at the forefront of innovation in the production system, introducing disruptive solutions and emerging technologies. Regions with a high rate of regular Internet users tend to exhibit higher levels of innovation and productivity. The correlation between Internet use and innovation is particularly evident in regions with advanced economies, where digitalisation has transformed entire sectors, from manufacturing to services. The positive relationship between productive system innovation and regular Internet users highlights the importance of policies that promote universal Internet access and digital literacy. Investing in digital infrastructure, ensuring net neutrality and supporting digital education are crucial steps to maximize the innovation potential offered by the digital age. In this context, a connected society is not only better positioned to adopt innovations but also becomes an active player in the innovation process itself.

- MEOS: the positive relationship between IPS and MEOS highlights how the digitalisation of public services contributes to creating an ecosystem favorable to innovation within production systems. This link underlines the importance of robust and accessible digital infrastructures not only to improve the efficiency and quality of life of citizens but also to stimulate economic growth and innovation in businesses. The digitalisation of public services improves accessibility and efficiency, reducing management times and costs for families and businesses. This frees up resources that can be invested in production or innovation activities. The presence of online public services encourages citizens and businesses to adopt digital technologies, increasing familiarity with digital tools and promoting a culture of innovation. Municipalities that offer services entirely online create new opportunities for companies to develop innovative technological solutions to improve interaction between the public and administration, thus stimulating innovation in the production system. Areas with a more digitalized municipal administration become more attractive to start-ups and high-tech businesses, which often seek a dynamic and facilitating environment to grow. Administrations that have undertaken digitalisation paths act as a catalyst for innovation within the community, improving not only the quality of services but also stimulating the local business environment. The digitalisation of municipal services for families is not only a means of improving the efficiency and accessibility of public services but also acts as a powerful stimulus for innovation within production systems. To maximize this potential, it is essential that digitalisation policies are accompanied by innovation support strategies, which include training, incentives for the adoption of new technologies, and the promotion of constructive dialogue between the public sector, businesses and citizens . In this way, the digital

transformation of municipal services can become a fundamental pillar for the development of an innovative and competitive economy.

There is a negative relationship between the value of IPS and the value of the following variables, namely:

- PTP: The negative relationship between IPS and PTP might seem counterintuitive at first glance, as it is commonly assumed that an increase in innovation translates into an increase in patenting activity. However, there are specific contexts and dynamics in which innovation within production systems does not necessarily translate into an increase in the propensity to patent. Let's examine some of the reasons that may support this seemingly paradoxical relationship. In contexts where open innovation prevails, companies may prefer to share knowledge and technologies through partnerships, collaborative platforms and licensing, rather than resorting to patenting, seen as a more restrictive and competitive means of protecting innovation. In industries characterized by a rapid technology life cycle, investing in patents may not be considered cost-effective or strategically advantageous, given the time and costs associated with the patenting process compared to the speed of technological obsolescence. Businesses may opt for other forms of innovation protection, such as trade secrets, inherent product complexity, or market lead time, especially when mandatory disclosure of information in a patent application may reveal critical details to competitors. Incremental innovation, which improves existing products or processes in an ongoing but not drastic way, may not meet the criteria of novelty and non-obviousness required for patenting, leading companies to focus on continuous improvement rather than legal formalization of the innovation. The negative relationship between the innovation of the production system and the propensity to patent illustrates the complexity of innovation and intellectual protection strategies within modern economies. This dynamic underlines the importance of a flexible and strategic approach to innovation management, which takes into account the specificities of the sector, the nature of innovation, and competitive dynamics, as well as the constant evolution of the legal and regulatory context regarding rights of intellectual property.
- AOC: a negative relationship between IPS and AOC may appear counterintuitive and, in fact, may require specific contextualization to understand, given that greater access to technology is generally assumed to facilitate innovation. However, there may be scenarios and interpretations that explain how and why such an inverse correlation could emerge under certain circumstances. It is important to highlight that, in general, access to technology and the Internet is an enabler for innovation, both at an individual and corporate level. An excessive availability and reliance on home technologies could result in a constant distraction for family members, reducing the time and attention dedicated to the deep learning and creativity that fuels innovation. In this scenario, technology, rather than being a tool of empowerment, becomes an obstacle to engaging in productive and creative activities. In some communities, a strong emphasis on domestic technological equipment could reflect and exacerbate existing disparities, where resources are allocated to maintain the technological status quo rather than investing in innovation initiatives in the production system or in training and development of digital skills necessary for effective use. productive of technology. The unlimited availability of technology and Internet access could limit opportunities for face-to-face socialization and the development of soft skills, which are crucial for collaborative innovation and leadership in the manufacturing context. The ability to communicate effectively, work in teams and solve complex problems can be weakened by excessive

technological isolation. A high availability of technology could orient users towards passive consumption of content rather than towards active production and innovation. This can lead to a culture where entertainment and media consumption prevail over creative exploration and the development of new ideas or products. The hypothetical negative relationship between the innovation of the production system and the home availability of computers and Internet connection raises important questions about the balance between technological access and productive use of technology. Encouraging conscious and goal-oriented use of technology, promoting digital education that emphasizes both technical and creative and critical skills, and supporting policies that balance access to technology with opportunities for personal and professional development are essential steps to transform the potential negative relationship into a positive interaction that supports innovation and productive growth.

6) Policy Implications

The detailed analysis of innovation across Italian regions, as demonstrated by thedata on the innovative production system, offers a valuable foundation for tailored policy recommendations aimed at enhancing Italy's regional innovation ecosystems. These policy implications and recommendations are critical for addressing the observed disparities and leveraging the unique strengths of each region to foster economic growth and competitiveness. To effectively enhance the innovative production system across Italian regions, policies must be multifaceted and region-specific. Highly innovative regions like Marche and Piedmont should receive continued support to sustain their innovation ecosystems through further investments in R&D, fostering industry-university collaborations, and incentivizing innovative activities among startups and SMEs. In contrast, regions with high-medium and middle-range innovation scores could benefit significantly from policies aimed at closing existing gaps in their ecosystems. This includes upgrading digital infrastructure, facilitating easier access to finance for innovation-driven projects, and encouraging a seamless transfer of knowledge between academic institutions and the business sector. Emerging and lower-scoring regions, in particular, require targeted interventions to jumpstart their innovation potential. Establishing regional innovation hubs, enhancing STEM education, and supporting the digital transformation of businesses are pivotal steps toward elevating their innovation landscapes. Moreover, across all Italian regions, the strengthening of digital infrastructure emerges as a critical foundation for innovation, underscoring the need for nationwide efforts to ensure high-speed internet access and the digitalization of public services. Industry-academia collaboration stands out as a powerful catalyst for innovation. Policies promoting joint R&D initiatives, innovation clusters, and practical learning opportunities can bridge the gap between research insights and market applications. Additionally, addressing the skills gap through improved STEM education and lifelong learning programs is essential for equipping the workforce with the necessary competencies in emerging technologies. Financial incentives, including grants, tax breaks, and investments in innovative startups and SMEs, are vital for stimulating innovation activities, especially in regions lagging behind. Such support should be carefully tailored to the specific needs and opportunities of each region to maximize impact. Lastly, embedding sustainability and inclusivity into innovation policies ensures that the benefits of technological advancement contribute to environmental goals and are equitably distributed across society. Supporting green technologies and social innovation projects can help achieve a more sustainable and inclusive innovation ecosystem. In conclusion, adopting a regionalized approach to innovation policy, grounded in the unique characteristics and strengths of each Italian region, is key to fostering a balanced and inclusive innovation landscape. This approach requires coordinated efforts across government, industry, academia, and civil society, aiming to create

a supportive environment for innovation that drives economic growth and enhances competitiveness throughout Italy.

7) Conclusions

The innovation of the production system grew on average in the Italian regions by 5% between 2004 and 2020. However, a significant gap remains between the more advanced North and the more backward South. The southern macro-region has grown significantly in terms of innovation of the production system. Improving the innovation of the production system in the Italian regions requires a multifactorial approach, which takes into account the territorial, economic and social specificities of each region. Increasing investment in research and development is essential to promote innovation. This includes financial support for universities, research centers and companies investing in R&D, as well as tax incentives for companies investing in innovation. Invest in higher education and professional training to develop advanced skills in science, technology, engineering and mathematics (STEM), as well as digital and soft skills crucial to the innovation economy. Encourage the creation of innovative clusters and technology parks that network universities, businesses and public institutions. This stimulates technology transfer, the sharing of resources and skills and the launch of innovative startups. Promote the digitalization of businesses and the adoption of emerging technologies such as artificial intelligence (AI), the Internet of Things (IoT), blockchain and biotechnology. This can increase efficiency and open up new business models. Facilitate access to financing for SMEs and startups, through investment funds, incentives, venture capital and crowdfunding. It is also important to offer support in the seed and scale-up phase of innovative companies. Investing in modern infrastructure, including broadband and efficient transport networks, which are essential for developing innovation and better connecting Italian regions to each other and to the rest of the world. Implement policies that reduce the gap between North and South and between urban and rural areas, ensuring that the benefits of innovation are distributed equitably across the country. Simplify bureaucratic procedures and create a regulatory environment conducive to innovation, which includes the protection of intellectual property and supports the experimentation of new solutions and business models. Encourage projects that combine technological innovation with sustainable development goals, including those that address social, environmental and public health challenges, thus contributing to more inclusive and sustainable progress. Support the internationalization of innovative companies, facilitating access to foreign markets through international networks, partnerships and participation in trade fairs and missions. Innovation is a key driver of economic growth and competitiveness. The adoption of these strategies, adapted to regional specificities, can help Italian regions to overcome existing challenges and fully exploit their innovative potential.

References

Acs, Z. J., Braunerhjelm, P., Audretsch, D. B., & Carlsson, B. (2009). The knowledge spillover theory of entrepreneurship. Small business economics, 32(1), 15-30.

Arora, A., Athreye, S., 2012. Patent incentives: returns to patenting and the inducement for research & development. Intellectual Property Office research paper (2012/20).

Arora, A., Athreye, S., Huang, C., 2016. The paradox of openness revisited: Collaborative innovation and patenting by UK innovators. Research Policy 45(7), 1352–1361.

Audretsch, D. B., Feldman, M. P., 1996. R&D spillovers and the geography of innovation and production. The American economic review 86(3), 630–640.
Audretsch, D. B., Coad, A., Segarra, A. 2014. Firm growth and innovation. Small business economics, 43(4), 743-749.

Audretsch, D.B., Belitski, M., 2019. The Limits to Collaboration Across Four of the Most Innovative UK Industries. British Journal of Management. doi. 10.1111/1467-8551.12353

Balland, P.A., Boschma, R., Frenken, K. 2015. Proximity and innovation: From statics to dynamics. Regional Studies 49(6), 907–920.

Beers, C., Zand, F., 2014. R&D cooperation, partner diversity, and innovation performance: an empirical analysis. Journal of Product Innovation Management 31: 292–312.

Bartelsman, E. J., Falk, M., Hagsten, E., & Polder, M. (2019). Productivity, technological innovations and broadband connectivity: firm-level evidence for ten European countries. Eurasian Business Review, 9(1), 25-48.

Belitski, M., Caiazza, R., Lehmann, E., 2019. Knowledge Frontiers and Boundaries in Entrepreneurship Research. Small Business Economics. doi 10.1007/s11187-019-00187-0

Denicolai, S., Ramirez, M., Tidd, J. 2016. Overcoming the false dichotomy between internal R&D and external knowledge acquisition: Absorptive capacity dynamics over time. Technological Forecasting and Social Change, 104, 57-65.

Duguet, E. 2004. Are R&D Subsidies a Substitute or a Complement to Privately Funded R&D? An Econometric Analysis at the Firm Level. Revue d‟ Economie Politique, 114(2), 245–274

ETI. Department of Enterprise, Trade and Investment. (2018). UK Innovation Survey, 1994- 2016: Secure Access. [data collection]. 6th Edition. UK Data Service. SN: 6699.

Gibbons, R., Murphy, K.J., 1990. Relative performance evaluation for chief executive officers. ILR Review 43(3), 30-S.

Giovannetti, E., Piga, C.A., 2017. „The contrasting effects of active and passive cooperation on innovation and productivity: Evidence from British local innovation networks. International Journal of Production Economics 187, 102–112.

Griliches, Z. 1979. Issues in assessing the contribution of research and development to productivity growth. Bell Journal of Economics, 10(1), 92-116.

Haltiwanger, J., Jarmin, R. S., Miranda, J. 2013. Who creates jobs? Small versus large versus young. Review of Economics and Statistics, 95(2), 347-361.

Helpman, E., Grossman, G. 1991. Innovation and Growth in the Global Economy, Cambridge, MA: MIT Press.

Hsieh, W. L., Ganotakis, P., Kafouros, M., & Wang, C. (2018). Foreign and domestic collaboration, product innovation novelty, and firm growth. Journal of Product Innovation Management, 35(4), 652-672.

Kaiser, U. 2002. Measuring knowledge spillovers in manufacturing and services: an empirical assessment of alternative approaches. Research Policy, 31(1), 125-144.

Knott, A.M., Posen, H., Wu, B. 2009. Spillover asymmetry and why it matters. Management Science 55, 373-388.

Kugler, M. 2006. Spillovers from foreign direct investment: within or between industries? Journal of Development Economics, 80, 444-477.

Lach, S., 2000. Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel. NBER WP 7943.

Lach, S., Sauer, R. M. 2002. R & D, Subsidies and Productivity. Maurice Falk Institute for Economic Research in Israel.

Roper, S., Love, J. H., & Bonner, K. 2017. Firms‟ knowledge search and local knowledge externalities in innovation performance. Research Policy, 46(1), 43-56.

Rosenbusch, N., Brinckmann, J., Bausch, A. 2011. Is innovation always beneficial? A metaanalysis of the relationship between innovation and performance in SMEs. Journal of Business Venturing, 26 (4), 441–57.

Scherer, F. 1982. Inter-industry technology flows and productivity growth. Review of Economics and Statistics 64, 627-634.

Stojčić, N., Srhoj, S., & Coad, A. (2020). Innovation procurement as capability-building: Evaluating innovation policies in eight Central and Eastern European countries. European Economic Review, 121, 103330.

Syverson, C. 2011. What determines productivity?. Journal of Economic literature, 49(2), 326-65.

Tomlinson, P.R. & Jackson, I. 2013. Cooperative ties and the impact of external factors upon innovation in an industrial district: some Insights from the North Staffordshire Table and Giftware Sector. Reg. Stud. 47–4, 580–596.

Van Ark, B., Inklaar, R., McGuckin, R. H. 2003. Changing gear–productivity, ICT and service industries in Europe and the United States. The industrial dynamics of the new digital economy, 56–99.

Declarations

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