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BRIDGING DEEP-TECH ECOSYSTEMS AND GLOBAL NEW INDUSTRIAL
POLICIES: A REGIONAL PERSPECTIVE

*CONECTANDO LOS ECOSISTEMAS DEEP-TECH Y LAS NUEVAS POLÍTICAS
INDUSTRIALES GLOBALES: UNA PERSPECTIVA REGIONAL*

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ABSTRACT

This study examines the effects of regional dimensions on deep-tech ecosystems by using a mixed methods approach that combines Principal Component Analysis with an in-depth case study. The dimensions arising from the data reveal significant regional dynamics and confirm territorial disparities in the presence and participation of key ecosystem stakeholders. Results show that the dynamism of deep-tech ecosystems is primarily influenced by funding diversity, institutional quality, and stakeholder collaboration. These insights contribute to a deeper understanding of how regional conditions shape deep-tech success and provide policy recommendations to enhance ecosystem resilience and innovation capacity.

Keywords: Technological change; Public policies; Entrepreneurship, Deep-tech ecosystem; Regional heterogeneity.

RESUMEN

Este estudio analiza los efectos de las dimensiones regionales en los ecosistemas deep-tech mediante una metodología mixta que combina el Análisis de Componentes Principales con un estudio de caso en profundidad. Las dimensiones que surgen de los datos explican significativas dinámicas regionales y confirman disparidades territoriales relacionadas con la presencia y participación de los actores clave del ecosistema. Los resultados indican que el dinamismo de los ecosistemas deep-tech está principalmente determinado por la diversidad de financiamiento, la calidad institucional y la colaboración entre los principales actores. Estos hallazgos permiten una mejor comprensión de cómo las características regionales moldean el éxito de la deep-tech y ofrecen recomendaciones de política para fortalecer la resiliencia del ecosistema y su capacidad de innovación.

Palabras clave: Cambio tecnológico; Políticas públicas; Emprendimiento; Ecosistema deep-tech; Heterogeneidad regional.

JEL Classification/ Clasificación JEL: O33; O38; R11; L26; R11.

1. INTRODUCTION

Since the early years of the 21st century, significant disruptions have shaped the global economy. These long-term trends encompass the slowdown in globalization, the imperatives of climate change mitigation, environmental sustainability, demographic shifts and the rapid pace of technological change (Guillen and Ontiveros, 2012). In relation to technological change, the digital divide has shifted from the national level (e.g., Comin and Hobijn, 2010) to the regional level (e.g., Crespo-Cuaresma and Lutz, 2021), highlighting the need to address the linkages between the global and regional dimensions of structural change. We are witnessing an unprecedented technological change with huge advances in areas ranging from artificial intelligence (AI) to biotechnologies, which have given rise to new emerging technologies. In this context, the need for governments to adopt a coordinating role in the domestic business sector has gained prominence among Western countries, as national and regional industrial policies have made a comeback. Most of this new generation of industrial policies consists of targeted, technology-focused, and mission-oriented strategies (Crisuolo et al., 2022), which inevitably require a more profound understanding of how regions internalize technological change.

Within the framework of new industrial policies, specific support for innovation and entrepreneurship in deep technologies is progressively bringing attention. In this debate, deep technologies correspond to the most advanced technologies located at the technological frontier (Aghion et al., 2021). They can be understood as disruptive innovations by promoting the appearance of new products in emerging or non-existent markets. However, there seems to be no universal consensus on how to define deep-tech and the absence of measures complicate their understanding for policy purposes.

The relevant place reserved for deep-tech within the innovation and industrial strategies is justified by its catalytic potential in terms of technological sovereignty and regional reindustrialization. This fact leads us to examine specific regional cases, such as the European Union, where recent advances aim to facilitate the adoption of deep-tech. This is primarily expressed in the European Commission's "New European Innovation Agenda" (2022) and in the recent Draghi (2024), report where the UE aligns with the United States and other global industrial leaders in the goal of strengthening the deep-

tech ecosystem¹. In this growing debate, the regional dimension associated with deep-tech cannot be neglected, given its reliance on the innovation and entrepreneurship ecosystem throughout its life cycle (Budden and Murray, 2019).

The objective of this study is to shed light on the dynamics of the deep-tech industry by identifying the key factors driving its emergence and development, with a focus on the regional dimension of the deep-tech ecosystem. To this end, we focus on the case of the Spanish deep-tech industry, using a novel database for Spanish regions. Although our access to data has been limited to Spanish context, the territorial data provides valuable insights for industrial policy both at the European Union level and globally. In line with the spatial disparities highlighted by the New Economic Geography (Krugman, 1991), we incorporate territorial factors to analyse deep-tech industry dynamics.

Previous research has qualitatively analysed the characteristics of the Spanish deep-tech ecosystem, but the consideration of the heterogeneity of its different territories has been left aside. To bridge this research gap, a twofold analytical methodology was employed. First, principal component analysis (PCA) was utilized for dimensionality reduction and to explore the relationships between representative variables of the deep-tech ecosystem in the 17 Spanish autonomous communities. Second, the quantitative approach was complemented by using a case study of a highly representative Spanish deep-tech venture. This specific case study highlights the critical role of the ecosystem in the emergence and consolidation of deep-tech ventures.

The article is organized as follows: in Section 2, we review first the literature that underpin the relationship between new industrial strategies and deep-tech and, secondly, the theoretical and analytic framework for deep-tech; in Section 3, we describe our methodology and database; in Section 4, we present our results; in Section 5, we discuss our main conclusions.

2. THEORETICAL FRAMEWORK

2.1. THE LINK BETWEEN THE GLOBAL RESURFACE OF INDUSTRIAL POLICIES AND THE RELEVANCE OF DEEP-TECH ENTREPRENEURSHIP

This section examines the theoretical relationship between new industrial strategies and the prominent role assigned to deep-tech. The analysis is set within the broader debate on industrial policy, highlighting the factors behind its resurgence and the key purposes of the renewed approach. Exploring the

1 Some of these deep-tech initiatives are: “National Nanotechnology Initiative”, “Drugan Orhan Act” in the USA; “Cybersecurity Program”, “Plan Deep-Tech” in Israel; “Stratégies d’Accélération”, “Plan France 2030” in France; “National Space and AI Strategy”, “Joint Action Plan on Standards for the Fourth Industrial Revolution” in the UK; “Industria 4.0”; National AI Strategy” in Germany; and the forthcoming “First Spanish Strategy Deep-Tech” in Spain <https://www.ciencia.gob.es/Noticias/2024/Mayo/cigudosa-congreso.html>

origins and objectives of current industrial policies clarifies the importance attributed to deep-tech entrepreneurship within them.

After World War II, the link between development and politics became central to academic and political debates. Industrialization was widely accepted as key to development, though views on industrial policy varied. From the 1980 onwards, neoliberalism criticized interventionist industrial policy for its biased selection and concentration around domestic champions (Autor et al., 2019). Major industrial economies shifted toward “horizontal policies” - transversally applied to all sectors of the economy to stimulate innovation and growth- (Acemoglu et al., 2006; Aghion and Howitt, 2006) while maintaining some traditional incentives. Meanwhile, some East and Southeast Asian economies retained traditional industrial policies to drive development and global integration (Amsden, 1989).

After years of neglect, industrial policy regained attention, especially after the 2008 financial crisis (O’Sullivan et al., 2013; Aiginger and Rodrik, 2020). Major industrial and developing nations explicitly implement non-horizontal measures, and even the IMF acknowledges that some once-heterodox policies may aid catching up in middle and low-income economies (Cherif and Hasanov, 2019).

The resurgence of industrial policies occurs in a complex global context marked by: i) industrial decline and job losses in advanced economies associated with production relocation and global value chain expansion (García and Fernández, 2021; Liboreiro et al., 2021; Andreoni and Gregory, 2013; Baldwin, 2012); ii) a new technological paradigm driven by disruptive technologies (Brixner et al., 2020; Pozi et al., 2021); and iii) a shift from globalization to “slowbalization” or “deglobalization,” as geopolitical, economic, and technological blocs gain dominance (Petricevic and Teece, 2019; IMF, 2024; Enderwick and Buckley, 2020).

The analysis of new industrial strategy narratives reveals three main goals. First, improving economic efficiency and productivity. Strategies focus on adapting to the new techno-productive model to maintain competitiveness (Diegues and Roselino, 2021). Advancing to the technological frontier requires active support, as technological progress is neither exogenous nor spontaneous (Andreoni and Chang, 2019). Therefore, the role played by governments can be justified by i) *Path dependence*, where accumulated infrastructure, investment, and capabilities create competitive advantages, warranting targeted interventions in key sectors like electric mobility, renewable energy, and robotics; ii) *Rapid technology adoption*, requiring coordination to exploit complementarities. Government intervention mitigates coordination failures, easing entry into high-cost, high-risk strategic sectors (Bolton and Farrell, 1990; Rob, 1991). This explains state success in the aeronautical industry (Boeing, Airbus) and deep-tech innovation (Azoulay et al., 2019). Deep-tech faces high market entry barriers due to asymmetric information, capital intensity, and uncertain returns, creating market failures. Effective coordination across government levels (national, regional, local) is essential to address

these failures (Kolev et al., 2022), compensating for weak private incentives to initiate deep-tech projects (Gosh and Nanda, 2010).

Secondly, security—both national and economic—has become a key driver of industrial policies. Growing instability and geopolitical fragmentation have made Western nations wary of dependence on external suppliers for critical products. In Europe, the Draghi Report (Draghi, 2024a) highlights the EU’s vulnerability due to reliance on foreign sources for critical raw materials, advanced technologies, and defense. It proposes a *European Industrial Strategy* focused on strategic autonomy and technological sovereignty. Earlier, the U.S., Japan, South Korea, India, and Australia had already prioritized control over key technologies for national security. Supporting deep-tech is central to this goal, as it fosters disruptive advancements and strengthens technological self-sufficiency in strategic industries. Defense R&D remains a proven catalyst for civilian innovation (Mazzucato, 2011; Moretti et al., 2019).

Finally, an innovative aspect of new strategies is their contribution to global social and environmental transformations. Industrial policies now go beyond the digitization of manufacturing and adopt a systemic approach, aligned with the mission-oriented model (EIM) proposed by Mazzucato (2011, 2018, 2020). The techno-productive paradigm will enable responses to challenges such as resource preservation and social challenges like aging populations, which require productivity increases to sustain economic growth (Draghi, 2024a). State intervention is crucial, as the private sector alone may not ensure sufficient R&D investment to effectively address global challenges. Within this narrative, supporting innovation and deep-tech entrepreneurship is key to tackling the most urgent global challenges—climate change, sustainable energy, and health—through collaboration among academia, industry, government, and society (Budden and Murray, 2019).

In conclusion, within new industrial strategies, deep-tech industry is positioned at the intersection of their three main objectives. First, it enhances economic efficiency and productivity through cutting-edge technologies, requiring targeted state intervention to overcome market barriers. Second, it bolsters national and economic security by strengthening technological self-sufficiency and reducing dependency on external actors. Finally, deep-tech is crucial for addressing global challenges, aligning with mission-oriented approaches to drive systemic transformation.

2.2. CONCEPTUAL FRAMEWORK FOR THE ANALYSIS OF THE INNOVATION AND ENTREPRENEURSHIP IN DEEP-TECH

This section explores the conceptual framework underlying deep-tech innovation and entrepreneurship, focusing on the relationship between deep-tech characteristics and the concept of ecosystem. It highlights the pivotal role of local advantages in shaping the geographic distribution of deep-tech companies. The term “deep-tech” lacks a widely accepted definition and is often linked to terms like “technology-based companies”, “disruptive technologies”



or “innovation-driven”. This work views “deep-tech” as a subcategory of high tech, distinct from digital tech and innovation-driven enterprises (Basilio, et al., 2022a).

The term “deep-tech” refers to innovative solutions based on scientific and technological advancements. While some focus on specific technologies to define deep-tech, economic literature leans towards a microeconomic perspective, emphasizing general features and market failures (Hafied, 2022). Deep-tech faces two main barriers of entry: i) high information asymmetry due to uncertain future returns, market demand, and scaling; and ii) significant capital intensity to address these uncertainties (Kolev et al., 2022).

Basilio et al. (2022a) identify five key criteria for defining deep-tech ventures: 1) positioned at the scientific knowledge frontier with uncertain and costly R&D cycles; 2) focused on tangible products and industrialization processes, with scaling challenges due to required expertise; 3) embedded in an interconnected ecosystem, especially linked to research institutions and universities; 4) problem-oriented, addressing grand challenges; 5) aimed at creating an “option space” to tackle multiple problems and scale profitably. Deep-tech ventures require novel approaches due to their unique time, capital, and uncertainty characteristics.

2.3. A MULTI STAKEHOLDERS APPROACH: THE DEEP-TECH ECOSYSTEM

Understanding deep-tech entrepreneurship ecosystems requires a comprehensive framework that incorporates social, cultural, political, and economic contexts. The “MIT framework for innovation ecosystem policy” developed by Budden and Murray (2018) divides the ecosystem into four elements: 1) *Foundational Institutions* (e.g., rule of law, property rights, freedom to innovate); 2) *Innovation-Capacity* (I-Cap) and *Entrepreneurial-Capacity* (E-Cap), driving the system—where I-Cap focuses on developing groundbreaking ideas and translating research, while E-Cap involves broader enterprise creation capabilities; 3) *Comparative Advantage*, reflecting a region’s unique strengths; and 4) *Generated Impact*, the outcome of I-Cap and E-Cap synergy with regional advantages. Optimizing I-Cap and E-Cap requires five key inputs: human capital, funding, infrastructure, demand, and culture/incentives.

This framework has been applied as conceptual and analytical model for deep-tech ventures (Basilio et al., 2022b), adapting it to include the specific needs that deep-tech promotion requires in I-Cap (high R&D intensity, extended time-to-market and significant capital needs) and in E-Cap (problem-focused entrepreneurship, deep interconnections with the ecosystem and a strong appreciation of complex technology). The MIT Framework underscores the importance of social cohesion, collective action and collaboration among stakeholders for building innovation ecosystems. The five key stakeholders of the deep-tech I-E ecosystem are: entrepreneurs, venture capital, academia, corporation and government. Each of which provide essential pieces to understand the dynamics of the deep-tech ecosystem, analysed as follows:

First, regarding *Entrepreneurs*, they play a crucial role in shaping policies and actions, with their perceptions of barriers varying across sectors, highlighting the need for a nuanced understanding. Some authors (Kriegesmann, 2000; Egelin et al., 2003) argue that success factors for spinoffs are mainly linked to the founders' motivations and characteristics (e.g., autonomy, risk profile), while others (O'Shea et al., 2005; Smilor and Matthews, 2004) emphasize environmental factors (e.g., capital availability, ease of patenting, IP transfer, ecosystem networks) and technology maturity (Heirman and Clarysse, 2004).

Second, *Venture capital* (VC) is private equity financing provided to high-potential, growth-oriented startups with the expectation of high returns as the business grows. VC funds are managed by firms that pool money from institutional investors, high-net-worth individuals, and other sources. Some VC firms specialize by sector (e.g., biotechnology, ICT) or focus on specific stages of startup financing (e.g., seed, early, or late-stage investment). VC helps reduce information asymmetries and adverse selection risks (Hafied et al., 2021), accelerates R&D, shortens time-to-market, and identifies new ideas and talented teams (Gonzalez-Uribe, 2013).

Third, *Academia* plays a multifaceted role (Etzkowitz, 2003) supplying scientific expertise, technical and scientific training, facilities and talent. It generates novel ideas and bridges the gap between research and application.

Fourth, *Corporations*, especially large ones, play a significant role in ecosystems by providing corporate venture capital (CVC), infrastructure, and talent. They are key players in value chains, both demanding deep-tech solutions and supplying inputs like technologies. Corporations also help scale smaller deep-tech ventures through acquisitions and exits.

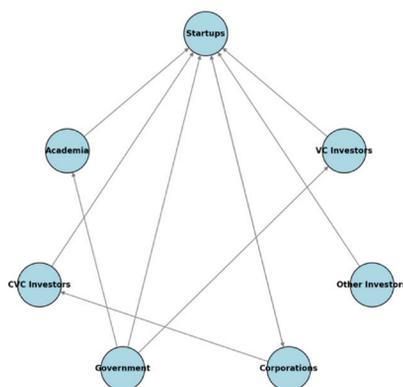
Finally, *Governments*, at national, regional, and local levels, shape ecosystems through rules, norms, and incentives². Their role is vital in addressing entry barriers, incentivizing private investment, and compensating for market failures in the deep-tech industry (Gosh and Nanda, 2010).

This framework emphasizes that each of the mentioned stakeholders is necessary in the innovation ecosystem but not sufficient by themselves. Effective deep-tech ecosystems require cohesion and collaboration across all actors to unlock the potential of deep-tech entrepreneurship and drive systemic change. Figure 1 summarizes stakeholders' relationships in the ecosystem.

Previous research on deep-tech has qualitatively analysed the characteristics of the deep-tech ecosystem but restricted to the Spanish case focusing on the role of key stakeholders and their strengths and weaknesses (Basilio et al., 2022b). This analysis considered the drivers of Innovation-Capacity and Entrepreneurship-Capacity: human capital, funding, infrastructure, demand, and culture/incentives (Budden and Murray, 2018). It highlighted a weak industrial sector driving market demand in Spain, marked by de-industrialization and small, low-tech companies. However, the study provided a general picture

2 This statement is very close to the universal definition of institutions proposed by North (1991).

FIGURE 1. STAKEHOLDERS IN THE ECOSYSTEM



Source: Authors' elaboration based on Budden and Murray (2019).

without considering the heterogeneity of its different territories (e.g. in terms of concentration of top-ranked universities, industrial activity, human capital, institutional setups or access to funding) and the relevance of the regional dimension for deep-tech entrepreneurship was not specifically considered.

To contribute to bridging this research gap and obtain territorial valuable policy lessons for the world economy, in this paper we exploit the heterogeneity stemming from the regional dimension to identify the critical factors influencing the dynamism of the innovation and entrepreneurship deep-tech ecosystems. Accordingly, the research hypotheses of this study are defined as follows:

H1: Funding diversity positively influences the emergence and survival of deep-tech ventures.

H2: The quality of regional institutions influences the emergence of deep-tech ventures.

H3: A lack of stakeholder cohesion is a significant barrier to deep-tech entrepreneurship.

3. METHODOLOGY AND DATA

3.1. METHODOLOGICAL APPROACH

The research methodology is twofold, integrating both quantitative and qualitative approaches to deepen the understanding of the research question. It combines quantitative methodologies, such as Principal Component Analysis (PCA) with a qualitative case study of Nanostine, a Spanish deep-tech venture in nanotechnology and nanoparticle coatings for advanced materials. This mixed method merges broader patterns identified by PCA with

an in-depth exploration of Nanostine’s specific context, operations, and unique characteristics, aligned with the microeconomic definition of deep-tech and key enabling technologies (KET).

PCA offers a baseline quantitative framework for dimensionality reduction and pattern identification (e.g., Bastianoni et al., 2008; Demšar et al., 2012; Argüelles et al., 2014), transforming variables into uncorrelated linear combinations (PCs) that capture data variability. The eigenvectors from PCA also provide insights into data structure, supporting the testing of hypotheses H1 and H2.

The seven explanatory variables used in the PCA are described in Table 1:

TABLE 1. PCA VARIABLES, RELATED STAKEHOLDERS AND DRIVERS

| Variable | Related Stakeholders | Related driver(s) I-Cap and E-Cap | Description |
|--|--------------------------------------|---|---|
| Venture Capital (VC) | Investors, Entrepreneurs | Funding | Financial support provided by private investors to early-stage startups. Entrepreneurs’ ability to secure and use funds effectively (Somaya and You, 2024) |
| Corporate Venture Capital (CVC) | Corporate, Entrepreneurs | Funding Demand | Direct involvement of corporations in funding startups. Startup-Corporate collaboration: promotion of knowledge transfer and commercialization opportunities. (Hafied et al., 2021) |
| Other Forms of Funding | Government, Entrepreneurs | Funding | Additional funding sources: public grants, subsidies, crowdfunding. Government’s role in financially supporting innovation and entrepreneurship, particularly in early-stage ventures (Kátay et al., 2019) |
| European Quality of Government Index | Government | Governance Human Capital | Governance quality and institutional support. Government’s role in fostering an inclusive business environment for innovation (Rodríguez-Pose and Di Cataldo, 2015) and human capital development (Acemoglu and Robinson, 2012) |
| Regional Gross Domestic Product per capita | Government, Corporate, Entrepreneurs | Infrastructure, Demand Culture and Incentives | Economic prosperity of a region influencing resources available for innovation and entrepreneurship |
| Number of STEM PhD Holders and Graduates | Academia, Government, Entrepreneurs | Human Capital | Academia’s role in producing skilled talent. Government investments in education and research. Entrepreneurs’ access to a skilled workforce (Etzkowitz, 2003) |

Source: Authors’ own elaboration.

PCA insights have been cross validated with the case study of Nanostine, a company classified as deep-tech in the Dealroom database³, that operates in the industry of nanotechnology for advanced materials. Nanostine complies with the deep-tech definition checklist proposed by Basilio et al. (2022a) and has received Neotec funds by CDTI, a public funding instrument highly valued by Spanish deep-tech entrepreneurs (Basilio et al., 2022b).

Case study analysis is a valuable qualitative method for exploring complex phenomena with multiple interrelated variables. It captures nuances often

3 The data source used in this paper.



overlooked by quantitative approaches and has been widely used in the literature, particularly to study emerging economic phenomena with limited prior data (Rocha and Urraca-Ruiz, 2012, Raymond et al., 2014; Nevzorova, 2022). It also enhances research reliability through data triangulation (Schwandt and Gates, 2017).

The objective of the in-depth study is twofold: first, to verify the relevance of identified patterns in real-world scenarios; second, to offer an illustrative example of a business operating within a specific regional ecosystem. The case study also illustrates and qualitatively supports H3.

While these findings cannot be generalized to all deep-tech ventures – not even to all nanotech ventures-, they offer a more nuanced understanding of a phenomenon still lacking a comprehensive analysis of the specificities affecting the endeavours of each deep-tech venture. In frontier technologies, the particularities associated with different stages of technological development are key to understand both innovation processes and solution success. Thus, in-depth case studies are particularly valuable in deep-tech entrepreneurship.

3.2. DATA AND SOURCES

Our panel data consists of observations from the 17 Spanish regions for the period 2016–2023. We incorporate a set of seven explanatory variables aligned with the key stakeholders and Innovation-Capacity and Entrepreneurial-Capacity drivers identified in the “MIT Framework for Innovation Ecosystem”. Although we are highly constrained by data availability, this dataset provides a preliminary glimpse into deep-tech dynamics.

Our primary data source is *Dealroom.com*, a private data platform that provides insights into the entrepreneurial ecosystem, to which we applied the filter for investment on deep-tech ventures. This source supplies information on the three key variables related to different forms of capital resources: venture capital (including both private VC and certain public investment instruments, such as the INNVIERTE Program by CDTI), corporate venture capital, and other forms of funding.

To measure regional institutional quality, we used the European Quality of Government Index, developed by the University of Gothenburg (Charron et al., 2014). Data on regional Gross Domestic Product (GDP) per capita is sourced from the Regional Accounting of Spain - Statistical Revision 2024 (INE), while information on the number of STEM PhD holders and graduates is gathered from the Ministry of Science, Innovation, and Universities (Spain).

Data for the in-depth case study relied on semi-structured interviews with Nanostine’s CEO, Daniel Gonzalez Muñoz, PhD. The first interaction occurred through the university teaching project entitle *Inventando la Rueda*⁴, which

4 These are the links to the episode dedicated to Nanostine. Spotify: <https://spotifycreators-web.app.link/e/pwqqxacKtPb> ; Ivoox: <https://go.ivoox.com/sq/2488601> ; youtube: https://youtu.be/pYa9myggf_E

promotes knowledge of the Spanish deep-tech ecosystem. These interviews provided detailed insights into the company's operations, complementing PCA-based analysis of explanatory variables. Topics covered included the company's history, technology, production process, ecosystem relationships, challenges, and opportunities.

4. RESULTS

4.1. QUANTITATIVE APPROACH: PRINCIPAL COMPONENT ANALYSIS

First, we show the results of PCA in Tables 2 and 3. The objective of the PCA is to identify unit-length ($L \cdot L = I$) linear combinations of the variables that capture the greatest variance. In the PCA results showed for the 17 Spanish regions, the territorial heterogeneity can be found when examining how the explanatory variables contribute to each one of the principal components, which can be defined as the linear combinations of the original variables.

TABLE 2. EIGENVALUES (CORRELATION MATRIX)

| Component | Eigenvalue | Difference | Proportion | Cumulative |
|-----------|------------|------------|------------|------------|
| Comp1 | 3.69 | 2.47 | 0.62 | 0.62 |
| Comp2 | 1.22 | 0.52 | 0.20 | 0.82 |
| Comp3 | 0.70 | 0.46 | 0.12 | 0.94 |
| Comp4 | 0.24 | 0.13 | 0.04 | 0.98 |
| Comp5 | 0.11 | 0.08 | 0.02 | 1.00 |
| Comp6 | 0.03 | | 0.00 | 1.00 |

TABLE 3. PRINCIPAL COMPONENTS (EIGENVECTORS)

| Variable | Comp1 | Comp2 | Comp3 | Comp4 | Comp5 | Comp6 |
|-----------|-------|-------|-------|-------|-------|-------|
| VC | 0.48 | 0.19 | -0.25 | -0.04 | -0.81 | 0.11 |
| CVC | 0.44 | 0.12 | 0.57 | -0.42 | 0.06 | 0.54 |
| Other F | 0.49 | -0.17 | -0.08 | -0.42 | 0.38 | 0.64 |
| GDPpc | 0.31 | 0.60 | -0.50 | 0.21 | 0.43 | 0.25 |
| EQI | -0.24 | 0.72 | 0.46 | 0.00 | -0.05 | 0.45 |
| STEMS Gr. | 0.44 | -0.18 | 0.39 | 0.78 | 0.08 | 0.12 |

Table 2 displays the eigenvalues of the correlation matrix, sorted by descending order. The corresponding eigenvectors are presented in Table 3. As shown in Table 2, the first three components account for over 94% of the total variance. Thus, the first three components offer the basis for interpreting the results.

In Component 1, there is a balanced contribution of the variables related to the role of investors in the ecosystem - Other Funding, Venture Capital (VC) and Corporate Venture Capital (CVC)- and Number of STEM Graduates. In Component 2 dominant variables are EQI (European Quality of Government Index) and GDP per capita, capturing socioeconomic and institutional factors.

In Component 3, there is a predominance of CVC and EQI, indicating a relationship between corporate investment and institutional environment.

Differing loadings in Table 3 show that the 17 regions have unique characteristics that affect their position in the PCs. For example, VC has a high weight in Comp1 (0.48) and a negative weight in Comp5 (-0.81), indicating that some regions have a high concentration of VC. On the other hand, EQI has a dominant weight in Comp2 (0.72), suggesting that this component captures institutional differences across regions.

Results of the Principal Component Analysis (PCA) provide insights that contribute to validating the previous research hypotheses (*H1* and *H2*).

H1: Funding diversity positively influences the startup and survival of deep-tech ventures.

The predominance of Other Funding, VC, and CVC across Component 1 and Component 3 highlights the importance of accessible and varied funding mechanisms within deep-tech ecosystems. *Component 1* underscores the impact of general investment sources, while *Component 3* specifically highlights the interaction between CVC and Institutional Quality (EQI).

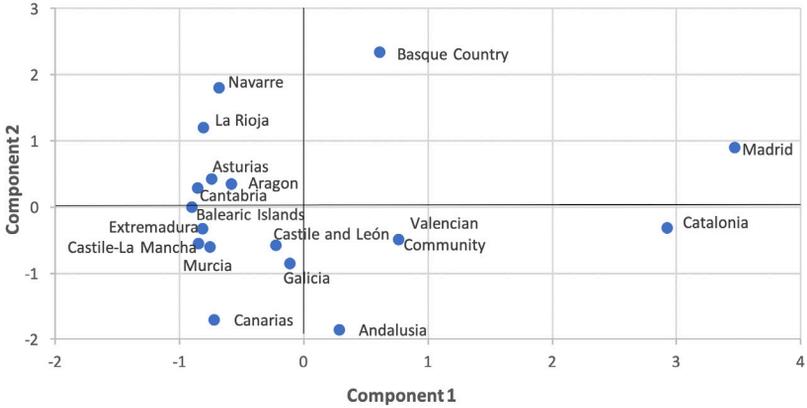
H2: The quality of regional institutions influences the emergence of deep-tech ventures.

Components 2 and 3 highlight the effects of Institutional Quality on regional deep-tech ecosystems: In Component 2, high loadings for EQI and GDP per capita suggest socioeconomic and institutional influences on the ecosystem, while Component 3 reveals the interaction between CVC and Institutional Quality. These findings align with prior research on institutional quality's impact at the subnational level (Rodríguez-Pose and Di Cataldo, 2015).

To better visualize regional differences (Figure 2), we projected each region onto the first two principal components (Components 1 and 2), after standardizing the values of the different variables considered in each case. This allows us to map their relative positions in a two-dimensional space where each axis represents a distinct underlying structure of the data.

The scatter plot in Figure 2 reveals four distinct regional profiles that mainly combine different levels of investment and talent attraction capacity (component 1) and institutional development (component 2). Regions in the upper-right quadrant score high on both components, indicating a favourable combination of financial, human capital and institutional conditions for deep-tech development. In contrast, other regions show divergent profiles: some with strong institutional quality but low investment (e.g. Navarre and La Rioja), and others with dynamic funding environments but weaker institutional indicators (e.g. Catalonia and Valencian Community).

FIGURE 2. RELATIVE POSITIONING OF SPANISH REGIONS IN THE PC SPACE



4.2. QUALITATIVE CASE STUDY: INSIGHTS FROM NANOSTINE

Nanostine, founded in 2020, is a spin-off of the Spanish National Research Council (CSIC) under the COMTE EBT program of CSIC General Foundation. The company operates at the scientific knowledge frontier and leverages its patented technology (developed over 15 years by CSIC researchers) to synthesize and apply nanoparticle coatings for advanced materials. With a strong foundation in scientific research, Nanostine’s technology enables precise control over nanoparticle size, composition, and distribution, offering high-value tangible applications across multiple sectors, such as aerospace, energy, sensors, and nanomedicine, through a business-to-business (B2B) model.

Illustrating hypothesis 1 and showing the positive influence of funding diversity on the survival of deep-tech ventures, Nanostine has obtained financing both from public (including the Neotec funds by CDTI) and private investors. Private investment has been essential in complementing public funding, with contributions from business angels and other firms. The gradual shift from public to private funding as the company matured highlights the role of investors in enabling scale-up and market entry.

Regarding the relevance of regional institutional quality for deep-tech, and illustrating hypothesis 2, the case of Nanostine evidences a high level of interaction with the ecosystem stakeholders beyond the sphere of investors.

First, regarding the importance of relationships with *academia*, Nanostine originated as a CSIC spin-off and benefits from the key foundational research conducted within this public research organization, although it currently does not maintain direct collaboration with universities, highlighting a gap



in bridging academia with entrepreneurial activities. In this sense, Nanostine recognizes the need to strengthen academia-industry connections, particularly during the scale-up phase, through programs like industrial PhDs and strategic partnerships.

Regarding collaboration with *government*, public sector support has been crucial for the company, particularly during its early stages. In this sense, the company has received key funding sources, including the Neotec grant (CDTI, 2022) and an ENISA loan (2023), which reflect the government's role in financing high-risk ventures. Similarly, the company has also benefited from regional programs like CataPullUP, and a Torres Quevedo contract.

In terms of relationship with the *corporate* sphere, Nanostine has developed diverse strategic alliances, such as a pilot program with Acciona and collaborations with Nano4Energy.

Moreover, Nanostine is strategically located in the Scientific Park of Madrid, offering access to talent, potential clients, events, and industry infrastructure. In this sense, the company highly values business incubation and acceleration centers, such as SPM and ESA BIC (Business Incubator Center of the European Space Agency) for their role in fostering the ecosystem. However, and according to Nanostine's Madrid's regional ecosystem advantages are tempered by challenges such as higher competition and operational costs, although its central location remains pivotal for scaling and accessing resources, underscoring regional factors' role in defining innovation ecosystem.

Accordingly, the case study results evidence that Nanostine's success depends on cohesive interactions with stakeholders in the innovation ecosystem and, hence, supports research hypothesis *H3: A lack of stakeholder cohesion is a significant barrier to deep-tech entrepreneurship*.

Academia provides the foundation of its technology, government supports early-stage development, and industry and investors drive scale-up and commercialization. To ensure sustained growth and promote cohesion between stakeholders, strengthening academia-industry collaboration and expanding public support during the scale-up phase can be considered as a must.

5. DISCUSSION

Considering the information provided by the PCA and the insights gained from the case study, our interpretation of the three PCs, in terms of their meaning within the deep-tech ecosystem is the following:

Component 1 represents a general axis of *financial and human capital intensity* which combines factors like VC, CVC, and other funding sources with the availability of STEM graduates. This component is likely to reflect the capacity of regions to support deep-tech ecosystems through funding mechanisms and technical talent availability, both especially relevant variables for the initial phases of start-up creation and the survival of deep-tech ventures through the long periods of uncertain technology development affecting initial TRLs and though the "valley of death" (Romme et al., 2023). That is,

Component 1 could be capturing the combined effect of two key drivers, Funding and Human Capital, from the MIT Ecosystem framework which are critical during the early stages of a startup's lifecycle, as evidenced by the case study of Nanostine. Regions scoring highly on this component are likely to host innovation hubs with ecosystems combining financial resources and skilled labour, highly attractive for deep-tech ventures.

Component 2 captures the role of *institutional quality and economic prosperity* in enabling deep-tech entrepreneurship. High-scoring regions tend to offer the infrastructure, stability, and early demand conditions needed to support ventures with complex technological and manufacturing requirements, as shown in the Nanostine case. In contrast, low-scoring regions may lack the institutional or economic capacity to attract and sustain such initiatives. Another explanatory hypothesis is that this finding could be related to administrative barriers in the public sector, which hinder entrepreneurship by increasing bureaucracy, delaying processes or raising compliance costs. Thus, Component 2 is likely capturing the joint effect of three MIT's drivers: Infrastructure, Incentives, and Demand, the latter driver being linked to phases closer to higher TRLs phases.

Component 3 reflects the importance of *corporate engagement in innovation ecosystems* and the supporting role of institutional quality. A high contribution of CVC suggests this component identifies regions where large corporations play a role in funding and developing deep-tech ventures. CVC plays a significant role as driver of initial demand, often key for attracting additional funding and surviving to the valley of death, but also for scaling-up and as a source of "exits" of the ventures (purchasing of the start-up by a corporate), often used as a sign of venture success. EQI's positive contribution indicates that strong institutions are also a significant enabling factor.

Finally, Figure 2 (regional scores in components 1 and 2) reinforces these interpretations by illustrating the spatial distribution of regions along the PCA axes and underscoring the fragmented nature of the Spanish deep-tech landscape. This finding aligns with previous analyses highlighting structural imbalances of the Spanish science and innovation system, with a high diversity of regional models (OECD, 2021). This regional disarticulation has been signalled to bear important effects in terms of knowledge transfer and collaboration differences across regions and in terms of complexity of policy governance (Ibid.), as well as fragmentation in terms of the deep-tech and entrepreneurial support systems (Basilio et al., 2022b). Figure 2 further evidences disparities regarding regional capabilities for attracting talent and financing (component 1) and in terms of institutional quality (component 2).

The different quadrants in Figure 2 allow to identify different regional cases for targeted public policy design. In this sense, an interesting result concerns regions located in the upper-left quadrant which, despite strong institutional and economic performance, rank low in investment and human capital attractiveness. In the opposite situation, we find some specific regions that, despite a lower institutional and economic performance, achieve to

attract high levels of funding and talent. These evidenced discrepancies may be linked to a global trend of polarization in technological development, where investment concentrates in a few leading innovation hubs (cities), leaving capable but less connected regions at a disadvantage. This finding suggests a need for targeted policies to better integrate regions into global innovation and investment networks. Strengthening local innovation ecosystems and promoting collaboration with leading hubs can reduce polarization and make these high-quality regions more attractive to investors.

6. CONCLUSIONS

In this paper, we examine how regional characteristics shape the development of deep-tech ecosystems. Our findings confirm the presence of territorial disparities in the effectiveness of deep-tech ecosystems across the 17 Spanish regions. Regions with a higher concentration of key resources—such as venture capital, corporate venture capital, and STEM talent—are better positioned to foster innovation and entrepreneurship within the deep-tech industry. The regions often considered “technology hubs” (e.g., Madrid, Catalonia, Basque Country) are more likely to attract funding and facilitate industrial collaboration, creating a virtuous cycle of innovation, in line with the previous insights offered by Acemoglu and Robinson (2012) when addressing inclusive institutions. By contrast, regions with more limited access to financial and human capital face significant barriers to participating meaningfully in deep-tech ecosystems.

These results suggest relevant implications for global policy. The recent resurgence of industrial policy could play a critical role in shaping the future of deep-tech ecosystems. The study indeed highlights how targeted governmental interventions, through specific channels such as public funding for R&D, could support for academic-industry collaboration, and incentives for venture capital, can be instrumental in fostering innovation. In a context marked by disruptive technological change and increasing interdependence, it is essential to understand and anticipate emerging technologies, including deep-tech. Global economic policy could benefit from leveraging territorial data to gain deeper insights into the complexity of technological change. Considering the recent calls to reindustrialize Europe (Draghi, 2024a, 2024b), a deeper understanding of technological dynamics is essential for designing effective industrial policies that are aligned with the challenges posed by technology-driven productive transformation.

This study has several limitations that open promising avenues for future research. First, data constraints limited our analysis to the 17 Spanish regions and imposed restrictions on time span. Second, inter-regional linkages, such as talent and resource flows, were not explored. Third, the dataset used presents certain limitations: for example, it lacks methodological notes on the specific definition of deep-tech used for classifying the ventures, and does not differentiate among types of investors (e.g. public vs. private VC), evidencing

the need to improve public data sources on deep-tech. Future research could address these limitations by expanding the geographical scope to include a broader set of regions beyond Spain, and incorporating longer time series to assess sustained impacts.

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