Introduction

What are the key factors of economic growth and development? This is one of the major question economists have been trying to answer since Adam Smith's classical work. For a long time, scholars focused on a single effect based on the *ceteris paribus* assumption. Capital, labor (human capital), innovation, technology, entrepreneurship, and institutions are amongthe most frequently examined factors. Over time, multiple factors and their interacting effects came into focus to explain the non-uniform effects of these classical factors. Ecosystem thinking, which emerged in the 2010s, attempts to measure complex systems with mutually interacting components, as well as feedback and forward loops.

Since the 2010s, entrepreneurship ecosystem (EE) research has increasingly moved beyond single-factor explanations of startup formation toward systemic, multi-actor perspectives (Acs et al., 2014; Stam, 2015; Stam & van de Ven, 2021). At the same time, digitalization has fundamentally transformed the opportunity structure, organizational forms, and modes of value creation in entrepreneurship (Nambisan, 2017; Autio et al., 2018). These developments have led to the emergence of the Digital Entrepreneurship Ecosystem (DEE) concept, which integrates digital infrastructures, user dynamics, institutions, and entrepreneurial agency into a coherent systemic framework (Szerb et al 2026). In this study, we focus on the DEE concept and rely on the components of the DEE Index in our empirical analysis.

Despite the conceptual richness of DEE research, its empirical evaluation remains methodologically fragmented. Composite indicators are widely used to measure ecosystem performance; however, different aggregation techniques –such as Principal Component Analysis (PCA), the Benefit-of-the-Doubt (BOD) model, and the Penalty for Bottleneck (PFB) approach –reflect fundamentally different assumptions regarding substitutability, systemic coherence, and compensatory dynamics. Consequently, ecosystem rankings and inferred policy priorities may vary substantially depending on the chosen methodology.

This paper addresses two central questions:

1. Methodological question**:** How do different composite indicator methodologies (PCA, BOD, PFB) shape the measured configuration of key DEE agents?
2. Substantive question**:** To what extent do these alternative DEE configurations explain variation in startup formation and digital venture dynamics?

By comparing three methodological approaches applied to the same set of DEE components, we contribute to both measurement theory and digital entrepreneurship research. We focus specifically on four entrepreneurial agency pillars –finance providers, key employees, support organizations, and digital technology providers –thereby isolating the "Digital Technology Entrepreneurship" (DTE) agency core of the DEE framework.

Theoretical foundations: From Entrepreneurial Ecosystems to Digital Entrepreneurship Ecosystems

Entrepreneurial ecosystems are conceptualized as territorially embedded systems of interdependent actors and institutions shaping entrepreneurial outcomes (Spigel, 2017; Stam, 2015). Early models were largely component-based and descriptive (Isenberg, 2010; World Economic Forum, 2013). Later contributions introduced systemic and evolutionary perspectives, emphasizing interaction effects, complementarities, and bottlenecks (Acs et al., 2014; Roundy et al., 2018).

Digitalization introduces three transformative shifts:

1. The blurring of geographic boundaries through digital infrastructures and platforms (Autio et al., 2018; Nambisan et al., 2019).
2. Platform-mediated opportunity structures (Kenney & Zysman, 2016).
3. Distributed, networked agency, extending beyond the individual entrepreneur (Nambisan, 2017; Sussan & Acs, 2017).

Consequently, the DEE framework differs significantly from the classical EE concept where digital technologies are not mere inputs or contextual variables; they are foundational and constitutive of the DEE. They transform how value is created, exchanged, and scaled, affecting every domain of the ecosystem.

The DEE Index, developed by Szerb et al. (2026) synthesizes these insights into four sub-indices – Digital Technology Infrastructure (DTI), Digital User Citizenship (DUC), Digital Multi-Sided Platforms (DMSP), and Digital Technology Entrepreneurship (DTE). Each sub-index includes three pillars adding up to twelve pillars in total; and each pillar constitutes both a digital and an entrepreneurship ecosystem variable component. In this study, we focus on the DTE agency components to evaluate how entrepreneurial agents operate within a digitally enabled ecosystem.

Multi-Agency in Digital Ecosystems

Classical agency theory (Jensen & Meckling, 1976) conceptualizes agency in hierarchical, principal–agent terms under conditions of information asymmetry. In contrast, entrepreneurial agency is rooted in entrepreneurship and institutional theory. It conceptualizes the entrepreneur not as a delegated actor, but as a creator and transformer of structures. According to Schumpeter (1934), the entrepreneur is an agent of creative destruction who introduces new combinations that disrupt equilibrium. Later opportunity-based theories (Shane & Venkataraman, 2000; McMullen & Shepherd, 2006) describe entrepreneurial agency as opportunity-driven, proactive rather than delegated, structurally transformative, and often operating under Knightian uncertainty. From an institutional perspective (Garud & Karnøe, 2001; Battilana et al., 2009), entrepreneurial agents reshape norms, practices, and institutional arrangements. In digital contexts, agency becomes increasingly distributed, networked, platform-mediated, and embedded in complex systems rather than hierarchical contracts (Nambisan & Zahra, 2016; Nambisan, 2017; Autio et al., 2018),. Thus, entrepreneurial agency is not primarily about solving alignment problems but about creating new value configurations, mobilizing resources, and altering systemic trajectories.

The DEE Index, at least partially, captures this distributed and relational form of agency. Here, entrepreneurial outcomes depend not only on founders, but also on other ecosystem players who actively contribute with the entrepreneur to the creation of new digital artifacts, startups and scaleups. In this study, we focus only on the startups. In particular, the DEE Index identifies three groups of key agency-players:

- Financiers (VCs, angels),
- Key employees (technical and managerial talent),
- Support organizations (accelerators, incubators),

In addition, digital technology providers (cloud services, APIs, data centers) could also be viewed as agents within the digital ecosystem. Altogether, these agents form an interdependent configuration. Figure 1 visualizes our conceptual model.

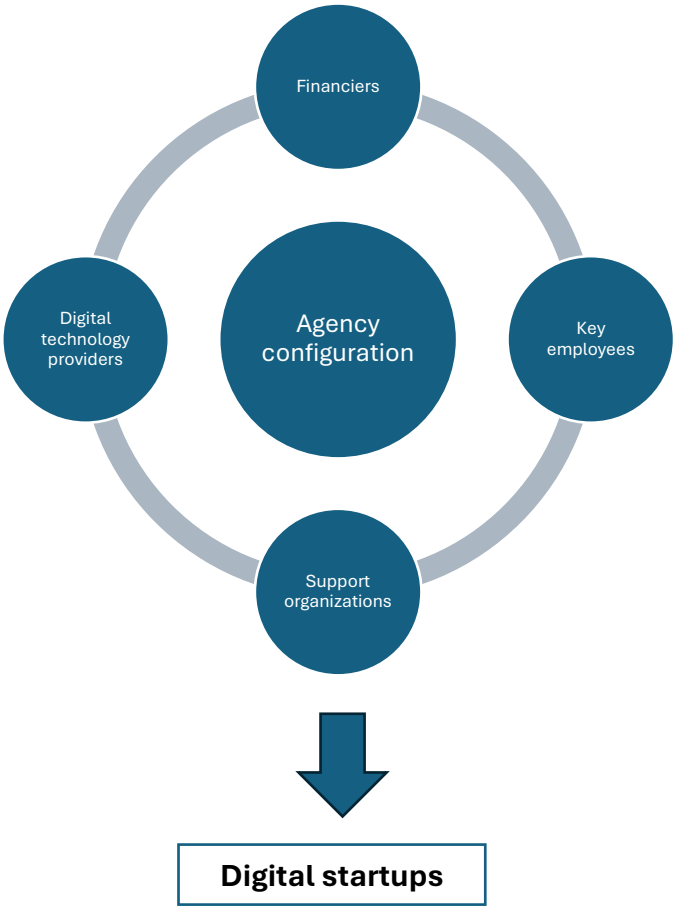

Figure 1: The conceptual model of digital entrepreneurial agency

3. The empirical research

We aim to examine the various agency configuration of the DEE and their effect on digital startups. The empirical analysis relies on the DEE dataset covering 170 countries for 2017–2022. To ensure institutional comparability and policy relevance, we focus on 40 European countries. Europe provides a natural laboratory for studying digital entrepreneurial ecosystems because:

- It exhibits strong heterogeneity in digital infrastructure and venture finance intensity.
- EU-level regulatory harmonization coexists with substantial national institutional variation.
- The period includes pre-pandemic (2017), crisis (2020), and post-pandemic adjustment (2022), allowing dynamic comparison.

Startup and digital venture data are obtained from Crunchbase, including total startup formation, technology-oriented startups, digital adopters and scaleups. The final dataset constitutes a country–year panel.

We apply and compare three aggregation methodologies. PCA derives weights endogenously based on variance–covariance structures. It assumes full compensability; i.e. a weak dimension can be offset by strength in another. PCA reflects statistical optimization, it may obscure systemic weaknesses.

The Benefit-of-the-Doubt (BOD) model, a DEA-type approach, assigns country-specific optimal weights under constraints. We use two weight structures: Model 1 constrains weights between 20–30%, and Model 2 between 15–35%. BOD emphasizes flexibility and performance maximization but allows compensatory dynamics.

The Penalty for Bottleneck (PFB) method (Acs et al., 2014) penalizes the weakest pillar, operationalizing partial-compensatory systemic logic. If one agency pillar underperforms, the overall composite score is proportionally reduced.

We conduct the examination in two stages. In the first stage, we use the three methods to compare the resulting configuration. The target variable is DEE score. In the second stage, we evaluate the connection of DEE agents with output variables, e.g. startups, technology startups, number of adopters. Specifically, we estimate panel regressions linking composite scores (by method) to startup indicators.

Preliminary Findings

Three key findings emerge:

1. Methodological divergence: PCA and BOD produce systematically higher and more dispersed scores than PFB, indicating strong compensatory effects in European ecosystems.
2. Explanatory power: All composite measures positively correlate with startup formation. However, PFB-based scores exhibit stronger and more stable coefficients for technology startups particularly in 2020–2022.
3. Crisis resilience: During the pandemic, ecosystems with balanced agency configurations (as measured by PFB) demonstrate greater startup resilience than those with highly uneven but compensatory configurations.

Taken together, these findings suggest that digital startup formation depends more on systemic balance than on isolated strengths.

Tentative Conclusions

Composite indicator methodology matters. Different aggregation logics produce systematically different ecosystem scores and potentially divergent policy implications. By comparing PCA, BOD, and PFB within a unified DEE framework, we demonstrate that methodological choices shape both scientific conclusions and regional policy diagnostics.

Contributions to Regional Science

This paper contributes in three ways:

1. Measurement robustness: It demonstrates that ecosystem rankings and policy diagnostics depend significantly on aggregation logic.
2. Regional digital entrepreneurship: It provides evidence that systemic complementarities are particularly important in digitally intensive sectors.

3. Policy implications: EU digital and innovation policy should avoid single-pillar interventions (e.g., VC expansion alone) and instead address ecosystem bottlenecks holistically.

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