



Complement or substitute? Productive and sustainable entrepreneurship in the innovation ecosystem

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ABSTRACT

Innovation ecosystems are increasingly expected to foster entrepreneurial activity that simultaneously supports economic growth and addresses pressing societal and environmental challenges. Yet, while prior research has examined productive and sustainable entrepreneurship largely in isolation, little is known about whether innovation ecosystems can enable both forms of venture creation and how their underlying logics interact. This study explores how innovation ecosystems enable two distinct entrepreneurial outcomes: productive entrepreneurship and sustainable entrepreneurship. Drawing on a unique dataset of 30 Italian smart city projects spanning 2011–2023, we examine ecosystem-level factors influencing each type and investigate whether the two forms can coexist and reinforce one another. Our findings suggest that innovation ecosystems could conducive to both forms of entrepreneurship, albeit through different mechanisms. Industry structure plays a stronger role in fostering productive entrepreneurship, while digital and technological infrastructure is more supportive of sustainability-oriented ventures. Moreover, we identify an asymmetric relationship between the two forms of entrepreneurship. Productive entrepreneurship is positively associated with sustainable entrepreneurship, but not the reverse. These results contribute to the innovation ecosystem literature by showing how economic and societal value creation interact within the same ecosystem. The study offers insights for scholars and policy-makers interested in designing ecosystems that support both innovative and sustainability-driven entrepreneurship.

1. Introduction

Innovation ecosystems are key frameworks for supporting innovation in an increasingly complex and interconnected world (Chaudhary et al., 2024). Traditionally defined as networks of interdependent yet autonomous actors—including firms, institutions, governments, and knowledge organizations—that collectively foster innovation (Autio et al., 2014; Jacobides et al., 2018), these ecosystems aim to generate and diffuse new ideas, products, processes, and technologies (Lucarelli et al., 2025). By highlighting complementarities among heterogeneous actors and resources, this perspective has proven particularly useful for explaining variations in innovation performance across regions and industries.

Entrepreneurship represents a key mechanism through which innovation ecosystems translate knowledge and technological advances into

economic and societal value (Autio et al., 2014; Guerrero and Siegel, 2024). Since Schumpeter's theory of creative destruction (Schumpeter, 1942) and Baumol's work on innovative entrepreneurship (Baumol, 2002), scholars have emphasized the role of entrepreneurial ventures in commercializing innovations, exploring new markets, and driving economic renewal (Agarwal et al., 2007; Nicotra et al., 2018). However, entrepreneurship does not emerge in a vacuum—it requires a supportive environment. The interaction among institutions, infrastructure, market structures, and policy mechanisms is crucial to providing access to knowledge, resources, and legitimacy (Autio and Thomas, 2013; Stam, 2015). In this respect, innovation ecosystems have become increasingly relevant not only for innovation itself but also as fertile ground for entrepreneurial activity (Guerrero and Siegel, 2024; Nambisan and Baron, 2013).

Innovation ecosystems may foster different forms of

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entrepreneurship, characterized by distinct objectives, resource requirements, and value creation logics. In particular, the literature has not yet reached consensus on whether the same ecosystem characteristics can simultaneously support both *productive entrepreneurship*—typically associated with innovation-driven growth, competitiveness, and employment creation (Guerrero and Siegel, 2024; Nicotra et al., 2018)—and *sustainable entrepreneurship*, which prioritizes the generation of environmental and social value alongside economic viability (Chaudhary et al., 2024; Volkmann et al., 2021). This gap is increasingly salient given the mounting pressure on innovation ecosystems to simultaneously deliver economic growth and contribute to sustainability transitions (Parrish, 2010; Polychronopoulos et al., 2024; Vedula et al., 2022). Productive entrepreneurship has long been recognized as a desirable outcome of innovation ecosystems due to its capacity to stimulate technological advancement, market dynamism, and regional development (Audretsch and Belitski, 2020; Nicotra et al., 2018). At the same time, global challenges such as climate change, social inequality, and resource scarcity have heightened the relevance of sustainable entrepreneurship as a mechanism for addressing societal needs through market-based solutions (Dean and McMullen, 2007; Vedula et al., 2022). While recent studies acknowledge that innovation ecosystems can adopt a sustainability orientation (Catala et al., 2023; Cobben et al., 2022), we still lack a clear understanding of whether and how the same ecosystem can foster both productive and sustainable entrepreneurship.

Moreover, the relationship between productive and sustainable entrepreneurship within innovation ecosystems remains theoretically and empirically underexplored. This may not be symmetric, as the mechanisms underlying productive and sustainable entrepreneurship differ in terms of resources, incentives, and constraints. These two forms of entrepreneurship are often portrayed as being guided by distinct logics, emphasizing innovation and economic value creation on the one hand, and social value creation on the other. As a result, sustainable entrepreneurship is sometimes viewed as emerging only when aligned with competitive advantage (Cohen and Winn, 2007; Dean and McMullen, 2007), while productive entrepreneurship is assumed to prioritize economic outcomes with limited concern for broader societal impact (Parrish, 2010). However, emerging evidence suggests that these forms of entrepreneurship may be interdependent rather than mutually exclusive. Productive entrepreneurship may enable sustainable entrepreneurship through knowledge spillovers, resource complementarities, and access to markets and infrastructures, while sustainability-oriented activities may reshape ecosystem priorities and institutional arrangements (Audretsch et al., 2023a; Sarma and Sunny, 2017). Whether such interdependencies are symmetric, and under what conditions they emerge, remains an open question.

Addressing this gap is critical for advancing innovation ecosystem theory. By moving beyond a unitary view of entrepreneurship, it becomes possible to better understand how ecosystems generate heterogeneous entrepreneurial outcomes and how different forms of value creation—economic and societal—interact within shared ecosystem structures. This perspective is particularly relevant in contexts where innovation ecosystems are explicitly designed to pursue both technological advancement and sustainability objectives. Accordingly, this study investigates the role of innovation ecosystems in fostering productive and sustainable entrepreneurship and examines whether—and how—these two forms of entrepreneurship interact within the same ecosystem. We address the following research questions:

1. What factors of innovation ecosystems are conducive to productive and sustainable entrepreneurship?
2. Do productive and sustainable entrepreneurship coexist and reinforce each other within innovation ecosystems?

To answer these questions, we conduct an empirical analysis based on a sample of 30 Italian smart city projects developed over a 13-year

period (2011–2023). Productive entrepreneurship is measured as the proportion of firms formally recognized as innovative under EU and Italian legislation. Sustainable entrepreneurship is measured using the share of ISO 9001, ISO 14001, and EMAS-certified firms. The measures we adopted are in line with extant literature. For productive entrepreneurship, it emphasizes the innovative-based component as suggested by Nicotra et al. (2018). For sustainable entrepreneurship, it respects the two aspects of sustainability highlighted by (Hertel et al., 2020): sustainable entrepreneurship in our study is compliant with the SDGs guidelines and provide solutions to address both social and environmental societal issues.

Our findings indicate that innovation ecosystems are conducive to both types of entrepreneurship, although through different mechanisms: industry structure plays a key role in productive entrepreneurship, while technological and digital infrastructure are more relevant for sustainable entrepreneurship. Furthermore, we find that productive entrepreneurship fosters sustainable entrepreneurship, but not vice versa, suggesting an asymmetric relationship. This study contributes to the innovation ecosystem literature by explicitly integrating entrepreneurship—both productive and sustainable—into the analysis. By identifying the ecosystem factors that support different entrepreneurial outcomes, we offer insights into how ecosystems can be designed to maximize both economic and societal value. Moreover, by examining the relationship between productive and sustainable entrepreneurship, we provide evidence on whether complementarities or trade-offs exist between these two outcomes.

These results contribute to several ongoing conversations in the innovation and entrepreneurship literature. First, by showing that innovation ecosystems can foster both productive and sustainable entrepreneurship (Theodoraki et al., 2018; Volkmann et al., 2021), albeit with different ecosystem components playing differentiated roles, we contribute to innovation ecosystem research that calls for greater attention to heterogeneous entrepreneurial outcomes (Chaudhary et al., 2024; Cobben et al., 2022). Second, by revealing an asymmetric relationship between productive and sustainable entrepreneurship—where productive entrepreneurship fosters sustainable entrepreneurship, but not vice versa—we contribute to recent debates on the complementarities and limits of mutual reinforcement between economic and societal value creation within entrepreneurial and innovation (Audretsch et al., 2023a; Jacobides et al., 2018). Third, by focusing on smart cities as innovation ecosystems, we show how entrepreneurship can be fostered without compromising sustainability objectives, as smart cities are explicitly designed to reconcile technological innovation with societal and environmental goals. (Kummita, 2018; Marchesani et al., 2025). In doing so, we contribute to debates on context-sensitive theorizing by illustrating how smart cities make visible the interaction between productive and sustainable entrepreneurship.

The rest of the paper is organized as follows. The next section lays out the study's theoretical foundations. By grounding our study in the innovation ecosystem literature, we develop two hypotheses in section 3. The first hypothesis concerns the role played by the innovation ecosystem in fostering productive and sustainable entrepreneurship, while the second hypothesis addresses the relationship between productive and sustainable entrepreneurship. Section 4 explains the methodology by presenting the sample, data, and empirical strategy that we adopted. Section 5 reports the results of the econometric analysis. Finally, Section 6 discusses the results by clarifying the theoretical contributions, practical implications, and limitations of the study and suggesting future research directions.

2. Theoretical foundations

2.1. The innovation ecosystem, productive entrepreneurship, and sustainable entrepreneurship

The concept of innovation ecosystems—as communities involving

diverse economic and social actors—has its roots in earlier studies of industrial districts (Marshall, 1890), innovation systems (Lundvall B.A., 1992), and clusters (Porter, 1998). Over the past thirty years, the term has evolved to describe a dynamic and network-based perspective that highlights the interactions among numerous stakeholders within the innovation process across different geographic levels (local, regional, or national), often used to explain variations in economic performance (Granstrand and Holgersson, 2020). Within this framework, innovation ecosystem actors work together to produce innovative outcomes that deliver value to specific target groups (Nicotra et al., 2018).

A compelling body of studies on innovation ecosystems has recognized productive entrepreneurship as a desirable outcome of innovation ecosystems (Guerrero and Siegel, 2024; Lucarelli et al., 2025; Nicotra et al., 2018). Productive entrepreneurship is commonly understood as a form of entrepreneurship characterized by high growth and strong innovative potential (Audretsch and Belitski, 2020; Stam and van de Ven, 2021; Wurth et al., 2022). It plays a significant role in enhancing the overall welfare of the regions in which it occurs (Audretsch and Belitski, 2020; Stam and van de Ven, 2021). Productive entrepreneurship contributes to job creation, lowers unemployment, drives innovation, opens new markets, and helps define the future of work. It also brings unexploited ideas or technologies to market, intensifies competition, and increases market efficiency, ultimately improving societal well-being (Nicotra et al., 2018).

According to the literature review from Nicotra et al. (2018), empirical research typically measures entrepreneurship through net firm entry, with start-up rates often normalized by contextual factors such as region, sector, or workforce characteristics (Audretsch and Fritsch, 1994). To more accurately identify productive entrepreneurship, some studies differentiate between *necessity-driven* and *opportunity-driven* entrepreneurs, recognizing only the latter as contributors to productive outcomes (Isenberg, 2011). Instead, the innovation dimension of productive entrepreneurship can be captured through the presence of innovation-based start-ups, often measured via patent ownership or citation metrics (Lerner et al., 2011). A performance-oriented approach uses data on high-growth start-ups, defined as young firms (typically less than 42 months old) with an average annual employee growth rate above 10% and a minimum of 10 employees at the onset of the growth period (Acs et al., 2009). These firms are considered key drivers of economic expansion and job creation.

Despite the primary importance that has been linked to productive entrepreneurship, innovation ecosystem outcomes can be highly heterogeneous (Audretsch et al., 2023a). Some can be more conducive to productive entrepreneurial innovations, while others can adopt a more sustainable orientation and foster sustainable entrepreneurship (Volkmann et al., 2021). Sustainable entrepreneurship is defined as a form of entrepreneurship which contributes to sustainable development (Parrish, 2010). Commitment to sustainability is hard to measure; the attempts done so far delineate two different perspectives (Hertel et al., 2020). The first one refers to the impact, namely the intended positive effects on targeted beneficiaries. Business cases investigated by Parrish (2010) suggested as examples: reducing encroachment and chemical use in watersheds; conserving a fringing coral reef; providing income, infrastructure, increased capacity, and market access to rural communities; improving local employment and professional development as well as environmental education. Examples of metrics include poverty reduction rates, job creation, health improvements, and the Social Return on Investment (Hertel et al., 2020). The second perspective refers to social responsibility. It evaluates the extent to which an organization's inputs and activities align with Environmental, Social, and Governance (ESG) standards (Hertel et al., 2020). Metrics include adherence to labor standards, environmental practices, and governance principles. Tools like B Lab's B Impact Assessment and SDG Action Manager are recommended for evaluating social responsibility (Vedula et al., 2022).

Scholars have started to recognize that a support system that incorporates actors, institutions, and resources can help entrepreneurs

innovate successfully and sustainably, consistent with regional and national goals (Fichter and Clausen, 2016). The profound association of entrepreneurship with innovation and, lately, sustainability led to the adoption of innovative ecosystems as the theoretical foundation of our analysis (Autio et al., 2014; Guerrero and Siegel, 2024).

3. Hypotheses development

The interactions between actors in innovation ecosystems thus result in productive entrepreneurship and sustainability-related outcomes (Volkmann et al., 2021; Wurth et al., 2022). Innovation ecosystems entail a variety of actors with distinct roles to play while being interdependent (Adner, 2017; Jacobides et al., 2018). These actors often include industry (i.e., producers, suppliers, and distributors) and technological factors, financial institutions, and research organizations (i.e., universities and research centers), as well as governments and regulatory bodies (Autio et al., 2014).

Industry structural conditions and resource munificence exercise salient influences on entrepreneurship, innovation, and sustainability. Inventions to be commercialized strongly rely on the involvement of private sector investments (Ritala and Almpapoulou, 2017) and actors (Adner and Kapoor, 2010; Overholm, 2015). Extant studies in the innovation ecosystem domain often depict large firms (in a high-tech industry) as the main players responsible for the ecosystem's innovation (Scaringella and Radziwon, 2018). However, as a single firm might not fulfill an ecosystem's value proposition, firms must deploy new capabilities to collaborate with other partners—the complementors (Silva et al., 2024). New entrepreneurial ventures can be one category of complementors interacting with incumbent firms by providing diverse types of specialized knowledge (Zahra et al., 2023; Zahra and Nambisan, 2012). Diversity within innovation ecosystems is key to their prosperity, as new opportunities can arise from other members' innovation activities (Zahra and Nambisan, 2011). In particular, the presence of sustainable entrepreneurial firms increases resource availability, as they tap resources that were previously inaccessible or underutilized (Surie, 2017), to develop sustainable products and services (Abdelkafi and Hansen, 2018).

In addition to industry-related aspects, technological aspects exercise an important influence on firm-level innovative activity (Autio et al., 2014; Garud et al., 2008). Technology allows entrepreneurs to gain new learning, create innovation paths, and develop new products and services (Dattee et al., 2018; Song, 2019). Moreover, it lowers transaction costs, reduces information asymmetry, and diversifies business scope and value creation (Chaudhary et al., 2024). Finally, it is crucial to solve the coordination problem among actors (Chauhan et al., 2022) and improve the quality of productive entrepreneurship (Endres et al., 2022). Technology and infrastructures, especially digital, can also help create and sustain new entrepreneurial ecosystems in which participants with different goals and motivations interact dynamically to conduct business and undertake entrepreneurial activities (Zahra et al., 2023). Kortus et al. (2025) explained well the need for digital and data infrastructures for innovation ecosystems devoted to circular economies. Storing and sharing data enable sustainable value creation through resource circularization by minimizing the use of natural resources and waste generation.

Universities contribute to productive entrepreneurship by conducting research and educating students (Audretsch and Lehmann, 2005). Moreover, universities support ecosystems by providing access to expertise and technologies (Civera et al., 2019) and by setting up internal arrangements, such as incubators and technology transfer offices, to encourage spin-off creation (Clarysse et al., 2014). At the same time, universities can support startup companies in developing sustainable products and services (Abdelkafi and Hansen, 2018). By incorporating sustainable-oriented courses, they can train and educate students who will become entrepreneurs in the future (Tiemann et al., 2018).

Finally, governance includes formal rules and norms that regulate

and incentivize entrepreneurial activities (Autio et al., 2014). It ensures stability and alignment among entrepreneurial actors' activities (Reiter et al., 2024). Thus, while each actor acts as an independent innovator, contributing complementary innovations to the ecosystem (Adner, 2017; Jacobides et al., 2018), if they do not converge to a coherent value proposition, the ecosystem's potential for value creation comes into question (Autio and Thomas, 2020). In a similar vein, Doblinger et al. (2019) pointed out the importance of governance in catalyzing innovations based on sustainability. The authors proposed that the patenting activity of sustainability-based innovations increases with increased government participation.

To summarize our line of arguments, the actors, institutions, and resources of innovation ecosystems can sustain both productive and sustainable entrepreneurship (Fichter and Clausen, 2016). Therefore, we posit the following hypothesis:

Hypothesis 1. Innovation ecosystems enhance the creation of both productive and sustainable entrepreneurship.

Consistent with prior literature, an ecosystem refers to the collaborative arrangements through which actors offer coherent customer-facing solutions (Adner, 2006). When coordination within the ecosystem's elements is inadequate, innovations fail (e.g., Adner and Kapoor, 2010). Collaboration flows increase innovation and provide advantages to all parties in the context of an overarching innovation ecosystem (Nylund et al., 2022). It is possible that as firms engage with one another, they also grow more aware of innovation ecosystem demands overall, thereby producing inventions that will benefit others. Overholm (2015) demonstrated how, in the solar panel industry, opportunity creation and discovery can be distributed among a community of entrepreneurs and that the ecosystem grows through collective efforts. Moreover, collaborations can lead to the achievement of competitive advantages for each actor involved (Scaringella and Radziwon, 2018).

Referring to productive and sustainable entrepreneurship, a strong collaboration pattern can emerge (Audretsch et al., 2023a). On the one hand, productive entrepreneurship can leverage its highly innovative content to provide what sustainable entrepreneurship may lack. Clarysse et al. (2014) referred to interactions based on mutual complementarity to illustrate it. In particular, external sources may be required to address internal weaknesses when a business cannot market a product or service due to a lack of internal competencies, innovative resource synergy, skills, and assets. Access to new markets and support for employment and growth provided by productive entrepreneurship can lead to the achievement of sustainable outcomes (Chaudhary et al., 2024; Spigel and Harrison, 2018). Hence, productive entrepreneurs can find new and creative solutions to societal challenges (Shepherd et al., 2015; Shepherd and Patzelt, 2011). On the other hand, sustainable entrepreneurship can be conducive to productive entrepreneurship (Audretsch et al., 2023b). Innovation ecosystems call for entrepreneurs to engage with governments, communities, and members of the public to change regulations and societal norms. They also advocate for green agendas and a more careful attitude toward the environment and promote increased environmental awareness (Schaltegger and Wagner, 2011; Soo Sung and Park, 2018). Randhawa et al. (2021) exemplified this by discussing how difficult it is for firms and their partners to create and capture value in the healthcare sector. In healthcare, therefore, patient welfare is prioritized, and even for individuals or organizations, pursuing private interests, regulations, and medical ethics results in constraints not seen in other industries. Sustainable entrepreneurship may help overcome this by fostering innovation without hindering underlying social value.

Within ecosystems, the collaborative efforts of heterogeneous actors lead to the realization of interdependent innovations with a greater purpose than they could achieve by acting in isolation (Adner, 2017; Jacobides et al., 2018). Sustainable entrepreneurship and productive entrepreneurship may therefore complement each other, leading to the implementation of a more complex value proposition (Dattee et al.,

2018): the development of sustainable innovation. Therefore, we posited the following hypothesis:

Hypothesis 2. Within innovation ecosystems, productive and sustainable entrepreneurship complement each other.

Fig. 1 summarizes our conceptual framework.

4. Methodology

4.1. Research setting and sample analysis

We adopt smart cities as empirical context for studying innovation ecosystem dynamics because they represent complex, multi-actor environments explicitly designed to orchestrate technological innovation, institutional coordination, and societal goals within the urban space (Appio et al., 2019; Camboim et al., 2019; Caragliu and Del Bo, 2022). Specifically, smart cities are evolving innovation ecosystems in which public authorities, firms, universities, and citizens interact through both formal and informal mechanisms to generate, diffuse, and recombine knowledge (Appio et al., 2019; Ciasullo et al., 2020). From an ecosystem perspective, smart cities are particularly relevant because they rely on orchestration processes, in which local governments play an active role in shaping complementarities among heterogeneous actors, resources, and capabilities (Linde et al., 2021). This orchestration function makes smart cities ideal settings for observing how innovation ecosystems evolve, how complementarities and trade-offs emerge, and how different forms of entrepreneurship are differentially enabled or constrained. Recent studies emphasize that smart cities embed both technological and value-based dimensions, where innovation outcomes are tightly coupled with societal challenges, sustainability goals, and legitimacy considerations (Sorri et al., 2024). In this sense, smart cities provide a fertile ground to examine innovation ecosystems that simultaneously pursue sustainability transitions, including green and socially oriented entrepreneurial initiatives (Jiang and Zheng, 2021; Schiederig et al., 2012) and an advanced economic environment (Marchesani et al., 2025; Schiavone et al., 2020). This dual orientation makes smart cities a particularly suitable context to investigate how productive and sustainable entrepreneurship interact within innovation ecosystems, and whether such interactions take complementary or substitutive forms.

4.2. Sample analysis

Our sample comprises data from 30 Italian cities spanning the 2011–2023 period. Italy served as a key case study in the smart city discourse as a central nation—near France and Spain—in the implementation of smart city initiatives based on the NetZero Cities project funded by the European Union.¹ Moreover, Italy occupies a central position in academic discussions on smart cities (Caragliu et al., 2011; Dezi et al., 2018; Vanolo, 2014). These two factors make it a compelling test case for analyzing the actual outcomes of smart city policies and emerging practical dynamics. Additionally, focusing on a single-country sample helps reduce institutional and legislative heterogeneity across regions, ensuring greater consistency in the interpretation of ecosystem dynamics. It also reduces potential biases stemming from cross-country differences in data collection and measurement methodologies.

To align this study with European Union standards and ensure generalizability across the European context, we employed a probability-proportional-to-size sampling approach, as outlined by Levy and Lemeshow (2008). In line with European policy benchmarks, the

¹ In 2022, the European Commission announced the selection of 112 cities for the “EU Mission for 100 Climate-Neutral and Smart Cities by 2030.” These cities, including 100 from EU Member States and 12 from Horizon Europe-associated countries, are receiving tailored guidance and support from the Mission Platform. Source: <https://netzerocities.eu/mission-cities/>.

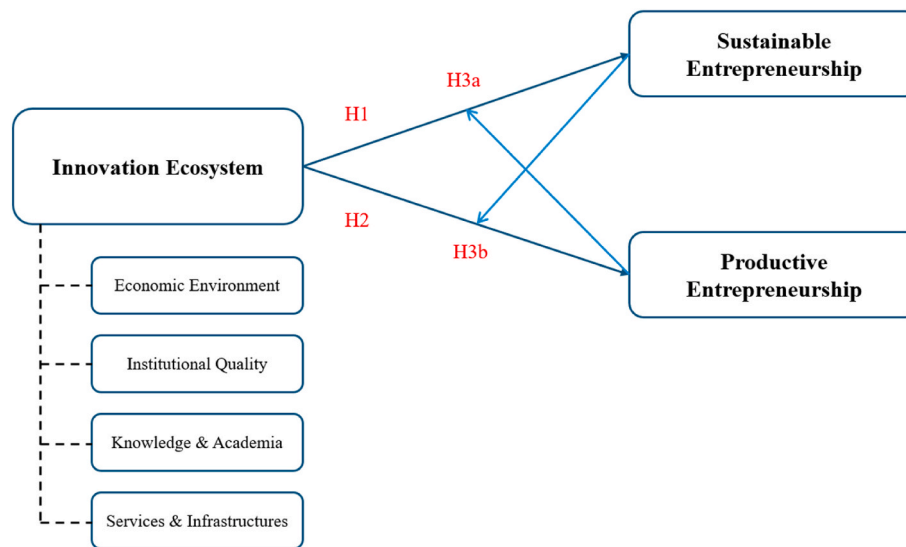


Fig. 1. Conceptual framework.

sample was stratified along three specific dimensions: (i) geographical location (i.e., North, Central, and South Italy), (ii) city size (i.e., small, medium, and large cities), and (iii) economic development (transitioning vs. economically developed areas). The final sample covers 30 Italian cities. In the North (12 cities), the sample includes Bologna, Milan, Turin, Genoa, Bergamo, Brescia, Verona, Modena, Parma, Trento, Pavia, and Venice. In the Center (6 cities), the selected cases are Florence, Rome, Pisa, Siena, Perugia, and Urbino. The South and Islands (12 cities) are represented by Naples, Bari, Palermo, Catania, Salerno, Caserta, Messina, Reggio Calabria, Lecce, Foggia, Cosenza, and Cagliari. In terms of size, the sample ranges from large metropolitan areas exceeding one million inhabitants (e.g., Rome, Milan, Naples) to medium-sized cities between 200,000 and 500,000 residents (e.g., Bologna, Florence, Bari, Catania), and medium-small urban centers below 200,000 inhabitants (e.g., Urbino, Pavia, Cosenza), ensuring representation across diverse strata. This approach ensured that the sample accurately reflected the Italian context while remaining aligned with broader European standards. The final sample represented 61% of the population of Italy's 100 largest cities, providing extensive coverage for analyzing smart city phenomena.

4.3. Data collection and variable description

This study utilized a unique longitudinal panel dataset aggregated at the city level, constructed using both primary data (collected through the Wayback Archive) and secondary data from national and international sources. Table 1 provides a summary of the variables used in the analysis, detailing their sources, descriptions, and operationalization, which also include the variables viewed as controls in the model, selected based on urban agglomeration (Glaeser, 2000; Glaeser and Gottlieb, 2009) and smart city literature (Caragliu and Del Bo, 2022; Trencher, 2019). Below, we outline the variables employed in our model.

4.3.1. Sustainable and productive entrepreneurship

The variables *Sustainable Entrepreneurship* and *Productive Entrepreneurship* served as both dependent variables (*H1*) and independent variables (*H2*) to test the outcomes of the innovation ecosystem and to test complementary/substitutive effects in our model. To assess the *sustainable entrepreneurship* variable, we followed Abdi and Williams' (2010) approach by developing a composite index using principal component analysis (PCA). The analysis incorporated three key indicators—total number of ISO 9001-, ISO 14001-, and EMAS-certified

companies, each standardized by the total number of active enterprises registered with the Chamber of Commerce in each city per year. ISO 9001, while primarily a quality management standard, has been shown to integrate sustainability into operational processes by improving efficiency and reducing energy and material use. ISO 14001 directly targets environmental management systems, requiring firms to adopt structured practices to minimize emissions and waste. EMAS further emphasizes transparency and accountability, mandating verified environmental statements and continuous performance improvements. Taking together, these certifications capture the extent to which firms embed environmental and social responsibility into their strategies, and they are widely recognized as reliable proxies of corporate sustainability (see, i.e., Abid and Marchesani, 2025; Zimon et al., 2022). The PCA approach allowed us to reduce these multiple indicators into a single interpretable metric that captured the underlying dimensions of green certification. To align the index with established guidelines on green certification, we assigned greater weights to ISO 14001 and EMAS certifications (0.4 and 0.4), reflecting their emphasis on environmental management and sustainability practices, and a weight of 0.2 to ISO 9001 due to its potential impact (see Table 1 endnote). Specifically, we adopted the following process: First, we standardized the data based on the total number of active enterprises in each city annually. This normalization allowed for comparability across cities of varying sizes. Second, we conducted a PCA on the three standardized certification variables. Third, as previously explained, we weighed certifications to align with European Union guidelines that emphasize certifications' environmental impact. In doing so, this composite index reflected certified enterprises' annual value within each city, providing a consistent and comparable measure of corporate environmental engagement across the sample.

The *Productive Entrepreneurship* variable, according to the definition discussed earlier (Audretsch et al., 2023a; Chaudhary et al., 2024; Wurth et al., 2022), comprises firms that make specific investments in research and development and focus on leveraging applications (goods and services) through innovative technologies that go beyond traditional

Table 1
Descriptions and constructions of variables.

Variable	Description	Source
Sustainable Entrepreneurship		
Companies ISO 9001	Total number of ISO 9001-certified companies active in the city annually, operationalized over the total number of active enterprises registered with the Chamber of Commerce of the city annually. ^a	ISTAT-CoC
Companies ISO 14001	Total number of ISO 14001-certified companies active in the city annually, operationalized over the total number of active enterprises registered with the Chamber of Commerce of the city annually.	ISTAT-CoC
Companies EMAS	Total number of EMAS-certified companies active in the city annually, operationalized over the total number of active enterprises registered with the Chamber of Commerce of the city annually. ^b	ISTAT-CoC
Productive Entrepreneurship		
	Total number of innovative companies active in the city annually, operationalized over the total number of active enterprises registered with the Chamber of Commerce of the city annually.	ISTAT-CoC
Industry and Economic Environment		
Job Integration	New residents who work permanently and those who found a job within the first six months operationalized over the total number of new residents registered each year at the registration office.	ISTAT
Entrepreneurial Density	Measure of the city's entrepreneurial density calculated as the ratio of the number of active enterprises annually to the city's area in square kilometers (km ^b).	CoC-ISTAT
Private R&D Investment	Total number of private sector investments in R&D annually, operationalized over the total number of companies active in the city annually.	ISTAT
Governance		
Trust in Governance	Composite index that includes levels of trust (Parliament, judicial system, political parties, other institutions) considering city and regional indicators. ^c Survey-based variables with values ranging from [0–10], conducted among the active population in the city, in which 0 represents low trust and 10 represents high trust in governance.	Eligendo-ISTAT
Public R&D Investment	Total amount of expenditures and investments in innovative public administration activities per year, relative to the city's active population.	ISTAT
Smart Practices	Attainment of two or three Sustainable Energy Action Plan (SEAP) goals: A binary variable in which 1 indicates achievement, and 0 indicates non-achievement.	PAES
Knowledge and Universities		
Total Students	Total number of university students registered in universities located in the city per year, operationalized as a ratio to the city's population annually.	MIUR
Total Courses	Total number of academic courses (bachelor's and master's degrees) offered by universities located in the city per year, operationalized as a	MIUR

Table 1 (continued)

Variable	Description	Source
	ratio to the city's population annually.	
Academic Spin Off	Total number of companies that have either a university or at least one academic among the founders operationalized over the total number of active companies in the city annually. ^d	Spinoffitalia.it
IT Service and Infrastructure		
Public Transportation Mobility	Total number of infrastructures implemented by the city, including railway (infrastructure and kilometers of track), bus routes (stops and buses), and bike sharing services (stations and vehicles), operationalized as a ratio to the population annually. ^e	WayBack Archive ^f - ISTAT
Digital Services	Total number of online services offered by the city on the official portal annually, accessible to users (since 2018 via digital identity).	WayBack Archive
Airport	Total number of airports (both public and private) located within the city's territory, including those within a 70 km radius.	Assoaeroporti.it
Control Variables		
GDP	Gross Domestic Product (GDP) produced in the city for a given year.	EUROSTAT - ISTAT
Total Companies	Total number of active firms registered in the city's chamber of commerce. This measure is normalized by the city's population to ensure comparability across locations and time periods.	IBS
New Companies	Total number of newly registered firms in the city, as recorded by the Chamber of Commerce each year. This measure is normalized by the city's population to ensure comparability across locations and time periods.	IBS
Employment	Proportion of the city's potential labor force currently employed measured as the natural logarithm of the percentage of employed individuals relative to the city's total population.	ISTAT
City Development	A categorical variable based on GDP per capita to distinguish cities with varying degrees of economic prosperity. According to European Commission guidelines, cities with GDP per capita below €30,000 are coded to reflect lower development, while those above €30,000 indicate higher economic development.	ISTAT
City Size	A binary indicator differentiating medium size from large cities. Cities with a population greater than 300,000 are coded as 1, whereas those below this threshold are coded as 0.	ANPR-ISTAT
Population	Total number of inhabitants in the city in a given year. This variable is employed in its natural logarithmic form to reduce skewness and facilitate statistical analysis.	ANPR-ISTAT
Criminality	Reported number of crimes within the city each year, as documented by official authorities. The natural logarithm is used to stabilize variance.	ISTAT
Housing Price	Average annual purchase and rental housing price per square meter within the city.	Immobiliare.it

Legend: ANPR (Anagrafe Nazionale della Popolazione Residente); Assoaeroporti.it; ISTAT (Italian National Institute of Statistics); CoC (Chamber of Commerce); EUROSTAT (European Statistical Database); Eligendo (Eligendo - Ministry of the Interior, DAIT); PAES (Sustainable Energy Action Plan); MIUR (Ministry of Education and Merit); IBS (Italian Business Register) Immobiliare.it (www.immobiliare.it/mercato-immobiliare/) Spin-off Italia (spinoffitalia.it); WayBack Archive (<https://wayback-api.archive.org>).

Note: All variables are measured on an annual basis over a 13-year period (2011–2023) for each individual city in the sample.

^a Although ISO 9001 is a quality management standard and not specifically designed for environmental or sustainability purposes (roles more directly addressed by the ISO 14001 standard), its principles of quality management, continuous improvement, and efficiency can significantly contribute to sustainability initiatives.

^b The Eco-Management and Audit Scheme (EMAS) registration is a voluntary environmental certification tool aimed at companies and public entities. It facilitates assessment, reporting, and improvement of environmental performance.

^c We consider the survey on trust in institutions (1–10) proposed by ISTAT regarding various actors and institutions, as well as data on electoral participation in cities (Eligendo) over the past 13 years. If no elections occurred, the value from the previous year is used.

^d We define an academic as a full, associate, or assistant professor, or a Ph.D. candidate, research fellow, or technician. The consideration of an academic spin-off is independent of a formal commitment from the parent university.

^e These data refer to urban strategic development funded by municipal, regional, national sources, and, since 2020, by the PNRR fund for green transition.

^f Adoption of the “Wayback Archive” allows us to access previous versions of the official website and retrieve past information, such as number of digital services, thematic areas, reports, communications, and financial reporting.

approaches.² Specifically, according to Article 4 of Decree Law 3/2015,³ a company is considered “innovative” if it meets the requirements set out in the European Commission Recommendation of 6 May 2003 (2003/361/EC) on the definition of micro, small, and medium-sized enterprises (SMEs). Regarding the specific investments in research and development (R&D), the firm must report R&D and innovation expenditure equal to at least 3% of the greater value between its cost of production and total production value. These expenditures must be clearly documented in the latest approved balance sheet and described in the accompanying notes. This ensures both formal classification and traceable financial validation of the firm's innovative status. This variable was calculated as the proportion of innovative companies active in each city annually, operationalized as the ratio of the total number of active enterprises registered with the city's chamber of commerce each year. By structuring the variable in this manner, we effectively captured the economic environment and assessed the relative presence of high-tech firms within each city, enabling a nuanced analysis of the relationship between urban ecosystems and high-tech business concentration.

It is important to note that, based on the adopted criteria, a firm may belong to both *Sustainable Entrepreneurship* and *Productive Entrepreneurship* categories. For instance, a company holding green certifications (e.g., ISO 14001) may also appear in the registry of innovative firms if it meets the required R&D intensity thresholds. While this partial overlap is possible, it does not affect the internal validity of our analyses, as the

² To operationalize this measure, we relied on official data provided by ISTAT and the Chamber of Commerce, as reported in Table 1. Specifically, we build on data provided yearly by the Italian National Institute of Statistics - <https://www.istat.it/it/files/2024/05/Rapporto-Annuale-2024.pdf>. It bases on the classification criteria used in the national registry of innovative firms, drawing on two institutional sources: the official portal for innovative start-ups (<https://www.registroimprese.it/start-up-innovative>) and the Ministry of Enterprises and Made in Italy (<https://www.mimit.gov.it/impresa/piccole-e-medie-imprese/pmi-innovative>).

³ Source: [https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legge:2015-01-24;3;vig=.](https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legge:2015-01-24;3;vig=:)

two variables are employed as separate dependent variables across distinct model estimations.⁴ Furthermore, as reported in Table 2, the correlation between *Sustainable Entrepreneurship* and *Productive Entrepreneurship* is relatively low, suggesting that they capture conceptually and empirically distinct entrepreneurial dynamics within the innovation ecosystem.

4.3.2. Innovation ecosystem

To construct the *Innovation Ecosystem* variable, we followed a critical examination of innovation (Oh et al., 2016) and the consequent effect at the city level (Cohen et al., 2016), developing a composite index based on the European Commission's guidelines for regional policies (Annoni and Dijkstra, 2013; OECD, 2008). The variables selected reflect four of the conceptual dimensions of innovation ecosystems: (i) Industry and Economic Environment, (ii) Governance, (iii) Knowledge & Universities, and (iv) IT Services & Digital Infrastructure. Within each dimension, we included three sub-variables—two aligned with the innovation ecosystem literature (Chesbrough et al., 2014; Oh et al., 2016) and one drawn from smart city literature (Cohen et al., 2016; Kummitha, 2020; Linde et al., 2021; Marchesani and Ceci, 2025; Mora et al., 2023)—to capture the nexus of the innovation ecosystem and smart city initiatives. This approach allows us to reflect not only the structural and relational features typical of innovation ecosystems but also the digital and governance-oriented capabilities that are increasingly embedded in urban innovation strategies. In smart cities, according to Kummitha (2020), these dimensions are not merely complementary but often co-evolving, shaping the institutional and technological conditions under which innovative and sustainable entrepreneurship can emerge. Table 1 presents the specific variables used within each dimension.

The process of constructing the composite index involves several steps to ensure robustness, consistency, and comparability across cities. First, we standardized the variables by applying a z-score transformation to each variable, reducing bias due to differing units of measurement. Second, to manage the data's multidimensionality within each dimension, we applied PCA to extract the primary component representing each dimension. This approach captured the maximum variance in each set of sub-variables while minimizing redundancy among highly correlated variables. The first principal component of each dimension was selected, as it explained most of the variance, providing a robust summary measure (Abdi and Williams, 2010). Third, although the European Commission's competitiveness framework suggests assigning greater weights to *Industry & Economic Environment* and *Governance* due to its critical roles in fostering entrepreneurial activity, we developed an equally weighted index to ensure balanced consideration of all dimensions, so as not to overlook the role of *IT Services & Digital Infrastructure* and *Knowledge & Universities*, considered central in the smart city paradigm (Camboim et al., 2019). Specifically, *Industry & Economic Environment* plays a foundational role in shaping the absorptive capacity of territories, supporting the scale-up of new ventures, and integrating sustainable practices while also contributing to co-creation mechanisms within the innovation ecosystem (Marchesani and Ceci, 2025). *Governance*, in turn, as pointed out by Mora et al. (2023), reflects the ability of local institutions to coordinate stakeholders, define shared priorities, and sustain policy continuity conditions that are particularly relevant

⁴ Note: The descriptive analysis reveals that firms contributing to the Sustainable Entrepreneurship measure (ISO 9001, ISO 14001, and EMAS certified) accounted for approximately 122,453 companies in 2023 across the 30 cities in our sample. In parallel, firms contributing to the Productive Entrepreneurship measure reached 143,217 high-tech companies in 2023, of which nearly 11,476 were registered as innovative SMEs, with a strong geographical concentration in Lombardy. In 2011, by comparison, sustainable-oriented firms numbered around 54,356, while 543 companies (subsequently registered at 2012) was not formally recognized innovative SMEs at that time according to the D.L. 179/2012 (lo “Startup Act”) e il D.L. 3/2015.

Table 2
Correlation matrix.

Variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
[1] Sustainable Entrepreneurship	1											
[2] Productive Entrepreneurship	0.230	1										
[3] Innovation Ecosystem	0.183	0.175	1									
[4] GDP	0.221	0.198	0.225	1								
[5] Total Companies	0.364	0.315	0.451	0.285	1							
[6] New Companies	0.312	0.293	0.395	0.274	0.416	1						
[7] Employment	0.177	0.155	0.372	0.193	0.351	0.381	1					
[8] City Development	0.184	0.192	0.344	0.178	0.225	0.240	0.331	1				
[9] City Size	0.164	0.201	0.216	0.402	0.341	0.197	0.205	0.194	1			
[10] Population	0.361	0.314	0.198	0.317	0.188	0.153	0.192	0.221	0.264	1		
[11] Criminality	0.234	0.261	0.115	0.199	0.215	0.227	0.216	0.183	0.188	0.484	1	
[12] Housing Price	0.216	0.197	0.146	0.386	0.144	0.148	0.173	0.197	0.143	0.596	0.288	1

for long-term smart city strategies. Moreover, *IT Services & Digital Infrastructure* provide the technological backbone for both innovation ecosystem and smart cities, enabling data-driven services, digital entrepreneurship, and enhanced citizen interaction (Linde et al., 2021). Finally, *Knowledge & Universities* are particularly important also in the innovation ecosystem, as the knowledge dimension captures the contribution of universities to local innovation through student presence, academic programs, and spin-offs. This is because, as pointed out by Audretsch et al. (2020, p. 9), universities are widely recognized as seedbeds for innovative startups and are considered fertile grounds for policy interventions aimed at boosting innovation activity. In doing so, each dimension's weighted principal components were aggregated into a single composite score using a weighted linear combination.⁵ The resulting index represented the *Innovation Ecosystem* variable, capturing the annual robustness and capacity of each city's entrepreneurial ecosystem.

4.3.3. Control variables

Extant studies have demonstrated that various intrinsic factors within the urban environment influence entrepreneurial outcomes in urban economics. Therefore, drawing on urban agglomeration (Fujita and Thisse, 2003; Glaeser, 2000), smart city (Caragliu and Del Bo, 2022; Marchesani et al., 2025), and entrepreneurial (Laursen et al., 2012; Schrijvers et al., 2021) literature, we controlled for both economic and city-specific characteristics.

In terms of city characteristics, we first included two binary variables as control: one indicating *City Development* (economically advanced or transitioning city) and another representing *City Size* (more or less than 300,000 inhabitants).⁶ Furthermore, we controlled for registered *Population*, as well as the factors *Criminality* and *Housing Price*, which are viewed as critical discriminants in both urban and entrepreneurial dynamics (Florida, 2002; Sampson and Wilson, 2005). Regarding the economic environment, we controlled for the total number of companies (*Total Companies*) and the number of *New Companies* to assess entrepreneurial development within each city. We also included *GDP* as a measure of economic development and *Employment* levels as an indicator of labor market integration, both of which are key factors in shaping entrepreneurial activity (Grilo and Irigoyen, 2006; Holmes et al., 2000). A detailed description of the variables and data sources is presented in Table 1.

⁵ To assess the index's stability, we conducted a sensitivity analysis by adjusting the weights and examining changes in index scores. This analysis confirmed the entrepreneurial ecosystem index's robustness across different weight configurations, indicating that the index provides a consistent measure of the entrepreneurial ecosystem's strength within each city.

⁶ To address binary variables' potential impact in the model, we also tested robustness by estimating it with and without these dummy variables. The results demonstrated stability across specifications, confirming that they do not alter the primary outcomes significantly.

4.4. Econometric approach

In this study, we employed the two-step system Generalized Method of Moments (GMM) estimator as the primary econometric approach. Based on Baum et al. (2003) and Roodman (2009), GMM is particularly suitable for our analysis due to its effectiveness in addressing endogeneity issues that arise from unobserved heterogeneity, measurement errors, and potential reverse causality between variables. To validate this choice, following Sakamoto et al.'s (1987) approach, we tested alternative models, including ordinary least squares, fixed effects, and generalized least squares. While the other models provided initial insights, GMM demonstrated superior robustness, particularly in handling endogenous variables and accounting for potential biases in a dynamic panel context (Roodman, 2009). Thus, we selected GMM over alternative estimation methods based on the estimations' robustness, its capacity to manage time-varying endogenous variables, and its adaptability to complex model structures (Bond and Arellano, 2012). Specifically, GMM used lagged levels and differences in the explanatory variables as instruments, effectively correcting for biases that might otherwise compromise the validity of the results. Thus, by offering a robust framework for managing endogenous explanatory variables, GMM ensured unbiased and consistent parameter estimates in dynamic panel data models (Roodman, 2009).

However, a limitation of this approach is that our model included multiple variables and sub-variables, each potentially influencing different aspects of *Sustainable Entrepreneurship* and *Productive Entrepreneurship*. To address this, following the approach proposed by Imai et al. (2010), we employed a causal analysis approach, as presented in Table 4, to assess the individual effects of specific variables on these outcome measures. This causal analysis, also adopted in the entrepreneurial literature (Moreno and Casillas, 2008), allowed us to isolate each variable's contributions, thereby enhancing the model's interpretive power by examining direct effects on the two primary outcomes.

To validate the robustness of our results, we conducted several diagnostic tests, including Wald chi-square, Hansen J-statistic, and the Arellano–Bond test for second-order autocorrelation (AR[2]). The Wald chi-square test assesses the joint significance of the model's parameters, indicating overall model fit (Roodman, 2009). The Hansen J-statistic evaluates the instrument set's validity, thereby confirming that our instruments are exogenous and appropriate for the model (Magazzini and Calzolari, 2020). The AR[2] ensures that no serial correlation exists in the error terms, thereby indicating the model's reliability (Bond and Arellano, 2012). These test results are presented in Table 3, indicating satisfactory performance on each metric. Furthermore, Table A1 presents descriptive statistics for the model variables, and a variance inflation factor (VIF) between 2 and 4, indicating no severe multicollinearity issues and further indicating our results' robustness (Akinwande et al., 2015). Specifically, to examine the conditional role of entrepreneurial dynamics, we extended the GMM model by incorporating two interaction terms: *Innovation Ecosystem* × *Productive Entrepreneurship* (Model IV) and *Innovation Ecosystem* × *Sustainable*

Table 3
GMM model results (sustainable companies and innovative companies as DVs).

	Sustainable Entrepreneurship as a DV				Productive Entrepreneurship as a DV			
	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII	Model VIII
Sustainable Entrepreneurship (n-1)	1.853*** [0.182]	1.738*** [0.167]	1.683*** [0.171]	1.664*** [0.176]				
Productive Entrepreneurship (n-1)					2.401*** [0.131]	2.367*** [0.129]	2.299*** [0.136]	2.284*** [0.124]
Innovation Ecosystem (IE)		0.776** [0.241]	0.782** [0.237]	0.764*** [0.215]		1.056*** [0.172]	1.108*** [0.164]	0.947*** [0.158]
Sustainable Companies						-0.294* [0.149]	-0.284* [0.152]	-0.271* [0.172]
Innovative Companies		0.430* [0.195]	0.445* [0.189]	0.413* [0.198]				
IE * Sustainable Entrepreneurship						-0.176* [0.086]		-0.189** [0.072]
IE * Productive Entrepreneurship		0.241** [0.118]		0.288*** [0.086]				
GDP	4.334** [1.701]		3.997** [1.573]	2.847*** [0.862]	3.943** [1.423]		3.680** [1.352]	3.593** [1.318]
Total Companies	1.656*** [0.511]		1.593** [0.704]	1.498** [0.671]	1.266** [0.498]		1.231* [0.512]	1.113** [0.399]
New Companies	0.456* [0.228]		0.421** [0.198]	0.384** [0.189]	0.516* [0.261]		0.504** [0.247]	0.531** [0.238]
Employment	1.337** [0.513]		1.255** [0.487]	1.216*** [0.364]	1.690** [0.457]		1.455** [0.510]	1.354** [0.482]
City Development	0.435* [0.216]		0.421* [0.221]	0.404* [0.203]	-0.524* [0.261]		-0.483* [0.242]	-0.393* [0.217]
City Size	0.280* [0.142]		0.331* [0.168]	0.302** [0.136]	0.267* [0.142]		0.251* [0.138]	0.279* [0.149]
Population	2.428** [0.792]		2.190** [0.744]	1.882** [0.712]	2.116** [0.846]		1.984* [0.812]	1.846* [0.798]
Criminality	-0.334** [0.154]		-0.352** [0.146]	-0.314** [0.142]	-0.469* [0.231]		-0.433* [0.219]	-0.405* [0.213]
Housing Price	0.781** [0.301]		0.776** [0.298]	0.733** [0.286]	0.983*** [0.298]		0.974*** [0.287]	0.937** [0.282]
City/Year Effect	Included	Included	Included	Included	Included	Included	Included	Included
Wald Chi ²	177.38	156.13	153.89	149.25	182.08	178.44	175.63	171.59
Hansen Test	48.66	51.54	53.07	56.21	36.13	37.39	38.71	39.23
p-value	0.248	0.252	0.294	0.237	0.116	0.109	0.121	0.137
Arellano-Bond (2)	1.58	1.43	1.52	1.45	1.42	1.40	1.47	1.52
p-value	0.115	0.153	0.129	0.146	0.155	0.160	0.141	0.127
N° Cities	30	30	30	30	30	30	30	30
N° Observations	360	360	360	360	360	360	360	360

Notes: DV: *Sustainable Entrepreneurship* (Models I to IV) and *Productive Entrepreneurship* (Models V to VIII). The Arellano–Bond test is used to detect potential auto-correlation issues and reports the z-statistic for second-order serial correlation in first-differenced residuals (two-tailed p-values). The Hansen test is employed to identify possible over-identification restrictions in the model, and the Wald chi-square test is utilized to determine the significance of a model's explanatory variables. The original panel includes 390 observations and were reduced by one year (30 observations) due to lagging in the evaluation of the independent variables' effect on the dependent variable in both models. *p < 0.05; **p < 0.01; ***p < 0.001. [Standard errors in parentheses].

Entrepreneurship (Model VIII). These interaction effects, estimated using lagged variables as internal instruments, allow us to test whether the ecosystem's influence on entrepreneurial localization is contingent on the existing presence of a specific type of firm. The use of lagged values (n-1) for both dependent and interaction variables ensures that we account for time-based causality and mitigate simultaneity bias. Our final models include robust standard errors, city and year fixed effects, and a full diagnostic test (e.g., Hansen J = 56.21, AR(2) = 0.146), confirming the consistency and validity of the instrument set.

5. Results

The results from the GMM estimations are presented in Table 3. Specifically, Models I–IV used *Sustainable Entrepreneurship* as the dependent variable, while Models V–VIII used *Productive Entrepreneurship* as the dependent variable. The models were estimated using a stepwise robust regression approach to control for potential inference issues and reduce econometric biases (Agostinelli, 2002). Models I and V highlighted the control variables' effect on the dependent variable. Models II and VI revealed the main variables' direct effects on the dependent variable. Models III and VII revealed the independent

variable's direct effect on the dependent variable, while Models IV and VIII highlighted the interaction effect, considering the complementary relationship within the model.

The results from Models III and VII support H1 (*Innovation ecosystems enhance the creation of both productive and sustainable entrepreneurship*). Specifically, in Model III, the parameter for the *Innovation Ecosystem* was positive and significant in explaining the relationship with the localization of *Sustainable Entrepreneurship* in smart cities ($\beta = 0.782$; $\rho = 0.001$), and as for Model VII, the parameter *Innovation Ecosystem* was positive and significant in explaining the relationship with the localization of *Productive Entrepreneurship* in smart cities ($\beta = 1.056$; $\rho = 0.002$). Taken together, these findings highlight that greater integration of the innovation ecosystem within smart cities positively influences the localization of sustainable companies and innovative companies. These results align with the smart city literature, as sustainability and technology are central to the smart city paradigm (Abid and Marchesani, 2025; Caragliu et al., 2011; Kummita, 2018). This perspective supports the contemporary view of cities anticipated by Florida et al. (2017, p. 86), who viewed cities as the very centers of innovation and entrepreneurship processes, highlighting that the synergy between innovation and entrepreneurship not only takes place in

Table 4
Causality analysis for innovation ecosystem variables.

Variable	Sustainable Entrepreneurship as a DV				Productive Entrepreneurship as a DV			
	Coefficient	Standard Error	z-statistics (β/SE)	p-value	Coefficient	Standard Error	z-statistics (β/SE)	p-value
Industry and Economic Environment	2.982	1.036	2.878	0.004	4.551	1.343	3.389	0.001
Job Integration	3.116	1.240	2.512	0.012	5.216	1.512	3.541	0.001
Entrepreneurial Density	1.554	0.576	2.697	0.007	2.982	0.870	3.448	0.001
Private R&D Investment	2.837	0.862	3.291	0.001	3.125	0.919	3.392	0.001
Governance	2.599	0.790	3.316	0.001	2.996	1.042	2.978	0.004
Trust in Governance	2.349	0.899	2.612	0.009	1.546	0.502	3.092	0.002
Public R&D Investment	3.004	0.913	3.287	0.001	4.382	1.623	2.698	0.007
Smart Practices	2.443	0.742	2.799	0.005	2.266	0.880	2.576	0.010
Knowledge & Universities	1.458	0.611	2.387	0.017	2.543	1.102	2.309	0.021
Total Students	1.331	0.609	2.183	0.029	1.662	0.937	1.986	0.047
Total Courses	1.143	0.443	2.577	0.010	2.088	0.878	2.653	0.008
Academic-Spin-Off	0.998	0.371	2.696	0.007	2.915	1.117	2.483	0.013
IT Service and Infrastructure	4.055	1.232	3.293	0.001	3.792	1.120	3.391	0.006
Public Transport Mobility	4.653	1.414	3.332	0.001	4.227	1.702	2.484	0.013
Airport	1.128	0.425	2.651	0.008	1.934	0.978	1.977	0.048
Digital Services	3.449	1.048	3.290	0.001	3.616	1.051	3.441	0.001

Legend: Coefficients (β) represent the estimated marginal effect of each innovation ecosystem dimension on the dependent variable. Robust standard errors measure estimation uncertainty, while z-statistics are computed as $z = \beta/SE$ and assess the strength of evidence against the null hypothesis. Reported p-values are two-tailed. Statistical significance follows conventional thresholds: * $p < 0.05$, ** $p < 0.01$, *** $p \leq 0.001$.

cities but also enables and requires them.

Models IV and VIII partial support H2 (*within innovation ecosystems, productive and sustainable entrepreneurship complement each other*). Model IV shows a positive and statistically significant interaction between *Innovation Ecosystem* × *Productive Entrepreneurship*, suggesting that the presence of productive entrepreneurship may reinforce the ecosystem's association with sustainable entrepreneurship. By contrast, in Model VIII, the interaction between *Innovation Ecosystem* × *Sustainable Entrepreneurship* is negative and statistically significant, indicating a weaker marginal association between the innovation ecosystem and *productive entrepreneurship* at higher levels of sustainability-oriented firms. Therefore, while a complementary effect emerges when productive entrepreneurship interacts with the innovation ecosystem to foster sustainable entrepreneurship, this pattern does not hold in the reverse direction. In this case, the interaction becomes substitutive, indicating that higher levels of sustainable entrepreneurship are associated with a weaker marginal effect of the innovation ecosystem on productive entrepreneurship.

The results in Table 4 offer a more granular understanding of how the core dimensions of the innovation ecosystem influence the localization of both sustainable and innovative companies in smart cities. First, *Industry & Economic Environment* emerges as a key enabler for both types of entrepreneurs, with high and significant coefficients for *Sustainable Entrepreneurship* ($\beta = 2.982$; $\rho = 0.004$) and *Productive Entrepreneurship* ($\beta = 4.551$; $\rho = 0.001$). This suggests that a dense and integrated economic fabric (with strong job integration, entrepreneurial density, and private R&D) creates fertile ground for both sustainable transitions and technological advancement. Second, the *Governance* dimension (including institutional trust, public R&D, and smart practices) shows significance across both models, confirming that effective coordination, transparent institutions, and public investment are crucial to aligning sustainability and innovation goals (β s ranging from 2.349 to 4.382, all $p < 0.01$). Interestingly, smart practices and trust-based governance are particularly impactful for *Sustainable Entrepreneurship*, highlighting their reliance on inclusive and legitimacy-driven governance frameworks, as also discussed by Mora et al. (2023). Third, *Knowledge & Universities* display a moderate yet consistent effect, especially through the presence of academic spin-offs and the overall educational offering. While not the strongest predictor, the university-related infrastructure still plays a vital role in both firm types, especially for *innovative companies* (e.g., $\beta = 2.915$ for academic spin-offs; $\rho = 0.013$), reinforcing the relevance of human capital pipelines and applied research, as anticipated by Audretsch et al. (2020). Finally, the *IT Services & Digital Infrastructure*

dimension shows comparatively larger and statistically significant coefficients across both dependent variables, with values exceeding $\beta = 4.0$ and $\rho < 0.01$ in several indicators. This confirms that smart urban infrastructures are not only foundational but also catalytic in attracting both *Sustainable* and *Productive Entrepreneurship*. In particular, digital services and public transport systems are shown to be particularly significant for *Sustainable Entrepreneurship*, suggesting a strong alignment between digital readiness and green entrepreneurship within the urban environment (Wang et al., 2021).

Figs. 2 and 3 graphically illustrate the deviation in the relationship. Specifically, Fig. 2 presents the positive deviation emerging in Model IV, revealing how localization of *Productive Entrepreneurship* amplifies the innovation ecosystem's effect on localization of *Sustainable Entrepreneurship*. However, Fig. 3 presents the results from Model VIII, in which interaction with *Sustainable Entrepreneurship* reduces the innovation ecosystem's effect on the localization of *Productive Entrepreneurship*.

6. Discussion and conclusions

In this paper, we empirically tested the role and configuration of innovation ecosystems in fostering both productive and sustainable entrepreneurship. Taking smart cities as a particularly suitable context, we offer an analysis of the characteristics of innovation ecosystems conducive to productive and sustainable entrepreneurship. Moreover, we provide evidence of the complementarity and substitution effects

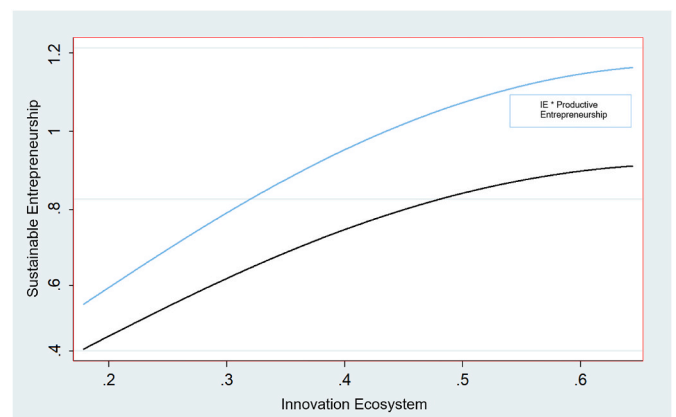


Fig. 2. Graphical representation of results (sustainable companies as a DV).

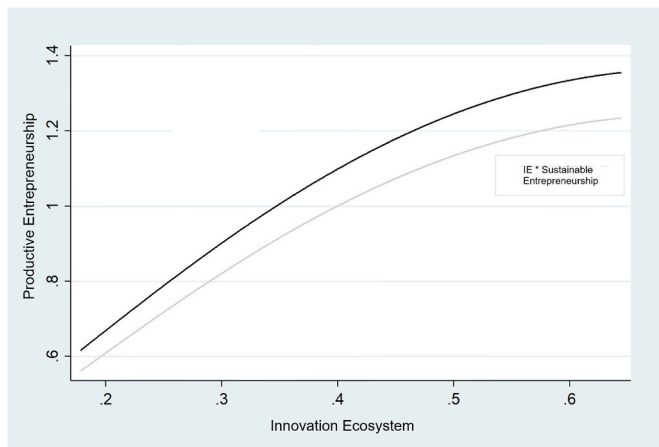


Fig. 3. Graphical representation of results (productive entrepreneurship as a DV).

that exist between the two.

Our study has implications for three major research streams: innovation ecosystems, productive entrepreneurship and sustainable entrepreneurship. We discuss each of these in turn.

6.1. Theoretical contributions

First, we contribute to the literature on innovation ecosystems by providing empirical evidence that innovation ecosystems may generate different forms of entrepreneurship (Autio et al., 2014; Guerrero and Siegel, 2024). We focus on productive and sustainable entrepreneurship, and we find that the traditional actors involved in ecosystems are enablers of both. Contrary to the previous literature on the topic, which emphasizes the fact that innovation ecosystems are heterogeneous, and specific characteristics generate specific entrepreneurship (Catala et al., 2023), we provide evidence that the same innovation ecosystem can be associated with heterogeneous entrepreneurial outcomes. In doing so, our findings also speak to emerging work on the microfoundations of entrepreneurial ecosystems by showing how ecosystem-level structures condition entrepreneurial opportunities, even when micro-level processes are not directly observed (Cosenz et al., 2023). Our findings reinforce the idea that sustainability and innovation are profoundly interrelated (Chaudhary et al., 2024) and that sustainable innovation ecosystems are not fundamentally different from traditional innovation ecosystems as suggested by sustainable ecosystem literature (see., Theodoraki et al., 2018; Volkmann et al., 2021). Although there exist shared enable elements (Cobben et al., 2022), some differences emerge in the relative importance of such elements in promoting the two entrepreneurship types. Industrial structure is particularly effective for productive entrepreneurship by confirming the relevance of private sector investments (Ritala and Almpantopoulou, 2017) and the complementarities existing between private actors (Zahra et al., 2023; Zahra and Nambisan, 2012). In contrast, sustainable entrepreneurship is strongly dependent on technological and digital infrastructures. The availability of digital technologies has opened a much broader set of opportunities for entrepreneurs (Nambisan and Baron, 2013), which leverage the potential of collaboration and collective intelligence design and launch more robust and sustainable entrepreneurial initiatives (Zahra et al., 2023; Zahra and Nambisan, 2012).

Second, we contribute to the literature on sustainable entrepreneurship by disentangling its role in the innovation ecosystem. In sharp contrast to the findings of the extant literature (Chaudhary et al., 2024; Volkmann et al., 2021), we provide evidence that sustainable entrepreneurship does not foster productive entrepreneurship. This is in line with Audretsch et al., 2023b, who found that the relationship between sustainable and productive entrepreneurship has diminishing marginal

returns. A potential explanation for this may be that a sustainable orientation generates organizational and transaction costs for entrepreneurs (Audretsch and Belitski, 2020). As the sustainable orientation of entrepreneurs will target both private and social gains, the conflict between the objectives and the costs associated with further investment in sustainable activities may overtake the marginal benefits. It is well established in the literature that the greater the portfolio of sustainable-oriented activities, the greater the market-end entrepreneurial opportunities (Volkmann et al., 2021). However, this factor negatively interacts with entrepreneurial learning processes for productive entrepreneurship, as it adds high complexity (Audretsch et al., 2023a). In contrast, we find that productive entrepreneurship fosters the creation of sustainable entrepreneurship. Sustainable entrepreneurship develops products, services, and processes that are committed to the sustainable development of societies and respect sustainability standards (Hertel et al., 2020). Resource efficiency, innovative solutions, and profit may not be their primary objectives. Being localized in an ecosystem with productive entrepreneurship can create collaboration dynamics so that they can benefit from activities and resources provided by innovative entrepreneurship (Clarysse et al., 2014). An alternative explanation could be that productive entrepreneurship is increasingly incorporating sustainability in its business model and strategy (Chaudhary et al., 2024; Spigel and Harrison, 2018). This is driven by the fact that sustainability challenges have reached unprecedented relevance and that governments worldwide have embraced ESG goals and priorities. Both explanations are in line with the *supermodular* complementarity in the meaning provided by Jacobides et al. (2018): for sustainable entrepreneurship, the additional availability of productive entrepreneurship is beneficial. In other words, productive entrepreneurship makes sustainable entrepreneurship more valuable. The fact that a directional or asymmetric complementarity appears to emerge from productive entrepreneurship to sustainable entrepreneurship and not vice versa is because complementarity is nongeneric and requires a specific structure of relationships (Jacobides et al., 2018). Recent evidence from open innovation research further suggests that the benefits of collaboration within ecosystems depend on actors' roles and affiliations, reinforcing the idea that complementarities are non-generic and unevenly distributed across ecosystem participants (Heaton and Min, 2025). This asymmetric pattern is consistent with recent views of ecosystem orchestration, which emphasize that coordination mechanisms operate unevenly across ecosystem layers, producing differentiated and sometimes non-reciprocal outcomes for entrepreneurial actors (Autio, 2022).

Third, we show how focusing on a specific empirical phenomenon—smart cities—can advance theorizing on innovation ecosystems beyond the focal context itself (von Briel et al., 2018). Smart cities constitute a particular setting because they intentionally combine technological innovation, sustainability goals, and multi-actor governance, making the mechanisms through which innovation ecosystems enable and differentiate entrepreneurial activity especially visible (Kummitha, 2018). By conceptualizing smart cities as innovation ecosystems rather than purely technological artifacts, we provide evidence that high levels of urban innovation do not necessarily crowd out sustainable entrepreneurship. This insight is particularly relevant in light of growing criticism questioning the actual sustainability outcomes of smart city development (Marchesani et al., 2025; Caragliu and Del Bo, 2022).

6.2. Practical implications

Our study identified the main drivers of entrepreneurship in innovation ecosystems, so policymakers could consider designing ad hoc policies to support specific ecosystems' elements based on their ultimate aim. Overall, setting policies in favor of innovation ecosystems is an effective strategy to promote entrepreneurship. Whether the objective is to enhance social entrepreneurship, they may want to focus mainly on

the service and infrastructure dimensions of the innovation ecosystem. Instead, if they want to enhance productive entrepreneurship within their ecosystems, private investments and the creation of a dynamic industrial environment are recommended.

However, the relationship appears to be more complex than this. Our study provides additional insights into the relationship between productive and sustainable entrepreneurship. Thus, while productive entrepreneurship appears to complement sustainable entrepreneurship, the reverse relationship does not emerge in our results. Policymakers should pay attention to what they really want to foster. By encouraging certain elements within innovation ecosystems, they can increase sustainability but at the expense of productive entrepreneurship. In contrast, encouraging productive entrepreneurship also elicits positive side effects on sustainability. This is particularly relevant given that the notable effort in promoting sustainability behaviors made by governments.

Finally, important implications for entrepreneurs can be derived. Entrepreneurs establishing innovative firms should privilege certain ecosystem characteristics that differ from those that benefit sustainability-driven entrepreneurs. Therefore, entrepreneurs should scan innovation ecosystems and privilege the presence of more effective actors for their business models. In this regard, entrepreneurial context plays a key role, as sustainability-driven entrepreneurs could take advantage of productive entrepreneurship, while innovation-driven entrepreneurs could be hindered by the presence of sustainable businesses. These considerations have relevant implications also for urban design, particularly in smart cities.

6.3. Limitations and future research directions

Our study also has limitations that suggest several avenues for future research. First, we consider industrial structure, technology and digital infrastructures, universities, and governance as the main interdependent actors' relevance within the innovation ecosystem. Nevertheless, other actors are part of the constellation of ecosystem elements, such as business angels and venture capital firms (e.g., Kaiser and Kuckertz, 2025), incubators and accelerators (e.g., Neumeier, 2022), science parks (e.g., Laspia et al., 2021), and venture studios (e.g., Moiana, D., Ghezzi, A., & Rangone, 2024). Moreover, the relational configuration among the actors matters (Khurana and Dutta, 2021), as it generates different types of innovation ecosystems. Previous research has proposed various classifications of innovation ecosystems based on several dimensions, such as how decision-making is structured (centralized versus decentralized), how open or restricted the ecosystem's boundaries are, whether the challenges being addressed are clearly defined or still evolving, and whether the innovations pursued are incremental improvements or radical breakthroughs. The literature identifies several examples of these configurations, including hub-and-spoke ecosystems, open-source networks, collaborative R&D alliances, and crowdsourced innovation models (Nambisan and Baron, 2013). Accordingly, entrepreneurship can play different role: breeder when it generates groundbreaking ideas capable of fundamentally reshaping the ecosystem's knowledge foundation; feeder when contributes an exceptionally high volume of innovations and discoveries within the ecosystem; niche player when identifies and cultivates a distinct segment within the ecosystem (Zahra and Nambisan, 2011). Along with the role played by entrepreneurial venture, the incumbent firms are fundamental for innovation ecosystems (Zahra and Nambisan, 2012). A more comprehensive perspective, including their roles, deserves further investigation. In this line, this study is limited to startups and SMEs, which, due to their higher strategic and operational flexibility, are more likely to adjust their locations in response to local ecosystem changes. While this focus allows us to better capture sensitivity to smart city transformations, it excludes large firms whose locational dynamics follow different logics and warrant separate investigation.

Second, together with technological advancement and sustainability

propulsion, other recent developments deserve to be examined. For example, the deglobalization process caused by the pandemic and ongoing regional wars is destined to impact innovation and entrepreneurial ecosystems and their configurations. This is particularly true because one of the main characteristics of innovation ecosystems is their lack of boundaries (Nambisan et al., 2019; Oh et al., 2016; Ritala and Almpantopoulou, 2017). We started to tackle this issue by examining smart cities. One way to think of smart cities is through a *global* approach, as Dameri et al. (2019) posited. A smart city is global because it is a phenomenon spreading throughout the world with some shared features and interdependencies, attracting investments, talents, and innovative firms. However, a smart city is also a local phenomenon because each city has unique characteristics and problems that policymakers can address only with specific solutions. It is sufficient to consider geographical and territorial specificities, cultural milieu, communities' needs and traditions, and other factors.

Third, concerning smart cities' sustainability and development, we illustrate the relevance of both the human and technological domains. Nevertheless, with reference to human factors, we focused, in particular, on educated people and the knowledge that they employ. We could not include citizenship's role in innovation, co-creation, and entrepreneurship in our analysis (Appio et al., 2019; Kummitha, 2018). Future studies may deepen this aspect within smart city literature. In addition, we have investigated productive and sustainable entrepreneurship, yet other forms of entrepreneurship can be considered in the smart city context, such as minority entrepreneurship (i.e., migrant entrepreneurship, female entrepreneurship, disability entrepreneurship). This would allow to effectively assess the inclusivity dimension of smart cities. In a similar vein other specific characteristic of smart cities could be interesting to study as enablers of inclusivity, such as the role of institutions, cultural openness, and social legitimacy.

Although the ecosystem dimension is relevant, and many research venues have been outlined so far, according to Felin and Foss (2023) and Cavallo et al. (2019), a different level of analysis could enhance our knowledge about the relationship between innovation and entrepreneurship. Firm-level and meso-level analyses are necessary to understand how and why innovation ecosystems have grown and developed in particular ways and how they can evolve over time (Zahra et al., 2023).

From an empirical perspective, measuring innovation ecosystems remains challenging. While we construct a composite metric to capture their multifaceted nature, developing an all-encompassing measure proved difficult (Oh et al., 2016). A further limitation is embedded in the scale of smart city context. These initiatives do not always evolve uniformly across the entire urban area, and their advancement may vary significantly between cities. Consequently, attributing citywide effects on entrepreneurial dynamics and sustainability standards to such projects may overestimate their overall impact. While we control for different levels of smart city advancement, the heterogeneous size and scope of interventions should still be considered when interpreting the results. In addition, our sample of 30 cities, although aligned with European Union policy frameworks and data availability, limits the generalizability of our findings to European countries. Future research could extend this analysis to non-Western contexts, where recent evidence suggests that innovation ecosystems play a critical role in facilitating sustainable entrepreneurship under different institutional conditions (Bakry et al., 2025). For instance, Latin America or Asia are regions with different smart city policies and cultural contexts, such as Latin America or Asia, where governance models, policy priorities, and resource availability may influence the development and dynamics of innovation ecosystems. Such comparative studies would deepen our understanding of how innovation ecosystems adapt across diverse sociopolitical and economic contexts, ultimately guiding policies and strategies that foster sustainable, inclusive, and resilient entrepreneurial environments, even amid global uncertainties, deglobalization trends, and the rapid advancement of deep-tech innovations.

Moreover, while our econometric design captures interaction-based

complementarities or substitution mechanisms through lagged moderation terms, we acknowledge that the underlying causal processes (i.e., technological spillovers or shared infrastructure effects) remain inferred rather than directly observed. Future research using micro-level or longitudinal firm-level data could further disentangle these mechanisms.

Furthermore, while the classification of firms into sustainable and productive entrepreneurship relies on official data and rigorous criteria, we acknowledge the possibility of partial overlap. Firms may meet both sets of requirements, particularly in cases where innovation and sustainability are integrated into their business models. Future studies may explore more granular firm-level data to investigate internal firm-level factors and understand, more specifically, the characteristics of

companies positioned across both innovative and sustainable categories.

CRediT authorship contribution statement

Alice Civera: Conceptualization, Writing – original draft, Writing – review & editing. **Filippo Marchesani:** Conceptualization, Data curation, Formal analysis, Methodology, Writing – review & editing. **David B. Audretsch:** Supervision.

Declaration of interest

Nothing to declare.

Appendix

Table A1
Descriptive Statistics

Variables	Vif	Median	Mean	SD	Min	Max
Sustainable Entrepreneurship	2.49	0.654	0.661	0.142	0.338	0.875
Productive Entrepreneurship	2.09	0.331	0.327	0.059	0.043	0.612
Innovation Ecosystem	1.55	0.574	0.581	0.168	0.186	0.991
GDP	3.88	0.982	1.019	0.245	0.455	2.155
Total Companies	2.01	0.648	0.661	0.212	0.216	1.411
New Companies	2.17	0.372	0.384	0.131	0.105	0.761
Employment	3.16	0.978	0.993	0.287	0.392	1.584
City Development	3.98	0.500	0.525	0.221	0	1
City Size	2.84	0.300	0.320	0.154	0	1
Population	2.16	0.703	0.716	0.187	0.556	1.147
Criminality	1.21	0.332	0.345	0.097	0.283	0.658
Housing Price	2.48	0.254	0.267	0.091	0.133	0.837

Data availability

Data will be made available on request.

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