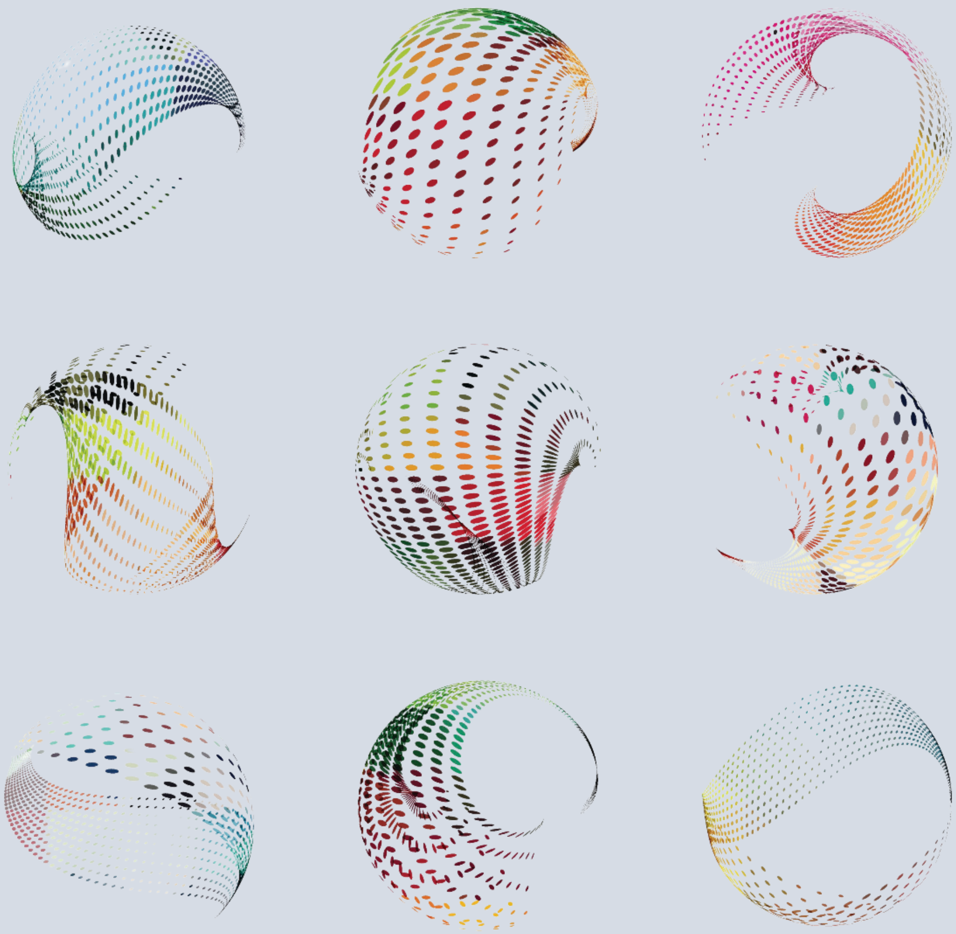
Entrepreneurial Ecosystems and Start-ups in Germany

Regional Approaches to Innovation & Ecological Sustainability



Blom Meijering

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Cover illustration: ivymany.

Voor Vincent, wiens onvoorwaardelijke steun de rode draad was in dit traject, en Appeltje.

Entrepreneurial ecosystems and start-ups in Germany: Regional approaches to innovation and ecological sustainability

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Reaching the end of this dissertation also marks the conclusion of a truly transformative journey – one that took me from moving to Germany and rapidly immersing myself in a whole new world at the BBSR, having to quickly develop my German to an academic level, to getting married, and now expecting a child. As I close this chapter, I look back on an incredible adventure, both personally and professionally.

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Summary

Start-ups are increasingly recognized as key drivers of both economic competitiveness and ecological sustainability in advanced economies. However, the geographical conditions that enable these dual objectives – particularly through the lens of entrepreneurial ecosystems (EEs) – remain largely unexplored. This is especially relevant in the context of Germany, which, despite its advanced economy, exhibits a globally underperforming and regionally uneven start-up ecosystem.

The overarching aim of this dissertation is to analyze how regional EEs contribute to two distinct yet complementary forms of entrepreneurship: product-innovative start-ups, which promote economic competitiveness through novel goods and services, and green start-ups, which embed ecological sustainability into their core business models. A regional approach is essential, as EEs are inherently place-based and shaped by locally varying social, economic, and infrastructural conditions that influence start-up success. Drawing on quantitative firm-level data from the IAB/ZEW Start-up Panel, this dissertation employs econometric analyses to examine the relationships between EEs and start-ups engaging in product innovation and green business activities at the regional level in three empirical papers.

The findings of the first paper (*Chapter 3*) show that EEs can influence product innovation in start-ups – but with varying effectiveness across regions. In particular, the urban-rural context plays a decisive role in determining how innovation drivers take effect. This highlights the need for place-sensitive policy measures to support product innovation across different regions. By contrast, the second paper (*Chapter 4*) shows that many EE components are not inherently unsuitable across region types but rather misaligned with the specific needs of green start-ups. The findings reveal a partial mismatch between existing EEs and the requirements of green start-ups – robust across urban, intermediate, and rural regions. This underscores the need for purpose-sensitive adaptations in EEs to overcome systemic lock-ins that inhibit green entrepreneurial activity. The third paper (*Chapter 5*) deepens this line of argument by investigating alternative, purpose-aligned ecosystem indicators. Using the example of cycling infrastructure, it demonstrates how physical infrastructure in traditional EEs can be reoriented to more effectively support green start-ups. The results show a statistically significant positive relationship between the share of cycling infrastructure and green start-up activity at the regional level in Germany – robust across urban, intermediate, and rural regions.

Taken together, the findings of this dissertation contribute to the theoretical advancement of the EE concept by underscoring the importance of purpose- and place-sensitive adaptations

for supporting diverse forms of entrepreneurial activity. Furthermore, the dissertation offers practical insights for regional policymakers seeking to foster innovation for competitiveness and ecological sustainability in Germany’s economy. It emphasizes the need for regionally tailored strategies and a reorientation of certain traditional EE components – such as targeted investments in cycling infrastructure.

Zusammenfassung

Start-ups werden zunehmend als zentrale Treiber sowohl wirtschaftlicher Wettbewerbsfähigkeit als auch ökologischer Nachhaltigkeit in entwickelten Volkswirtschaften anerkannt. Die geografischen Bedingungen, die diese beiden Ziele ermöglichen – insbesondere im Rahmen von unternehmerischen Ökosystemen (UÖ) – sind jedoch bisher weitgehend unerforscht. Dies ist insbesondere im Kontext Deutschlands von Bedeutung, da das Land trotz seiner wirtschaftlichen Stärke über ein im internationalen Vergleich unterdurchschnittlich leistungsfähiges und regional unausgewogenes Start-up-Ökosystem verfügt.

Das übergeordnete Ziel der Dissertation besteht darin, zu analysieren, wie regionale UÖ zur Entwicklung zweier unterschiedlicher, aber komplementärer Formen von Unternehmertum beitragen: Produktinnovative Start-ups, die durch neuartige Waren und Dienstleistungen zur wirtschaftlichen Wettbewerbsfähigkeit beitragen, und grüne Start-ups, die ökologische Nachhaltigkeit in ihre zentralen Geschäftsmodelle integrieren. Ein regionaler Ansatz ist hierbei essenziell, da UÖ ortsgebunden sind und durch lokal unterschiedliche soziale, wirtschaftliche und infrastrukturelle Faktoren geprägt werden, die den Erfolg von Start-ups beeinflussen. Die Dissertation stützt sich auf quantitative Unternehmensdaten des IAB/ZEW-Gründungspanels und verwendet mithilfe ökonometrischer Analysen die Zusammenhänge zwischen UÖ und Start-ups, die entweder Produktinnovationen umsetzen oder grüne Geschäftsaktivitäten verfolgen auf regionaler Ebene in drei empirischen Artikeln.

Die Ergebnisse des ersten Artikels (*Kapitel 3*) zeigen, dass UÖ Produktinnovationen in Start-ups beeinflussen können – allerdings mit unterschiedlicher Wirksamkeit in verschiedenen Regionen. Insbesondere der städtisch-ländliche Kontext spielt eine entscheidende Rolle bei der Wirksamkeit verschiedener Innovationsfaktoren. Daraus ergibt sich ein Bedarf an raumsensiblen politischen Maßnahmen zur Unterstützung von Produktinnovationen in unterschiedlichen Regionen. Im Gegensatz dazu zeigt der zweite Artikel (*Kapitel 4*), dass viele UÖ-Komponenten nicht grundsätzlich ungeeignet für verschiedene Regionstypen sind, sondern vielmehr nicht auf die spezifischen Anforderungen grüner Start-ups ausgerichtet sind. Die Ergebnisse deuten somit auf eine teilweise Fehlanpassung zwischen bestehenden UÖ und den Bedürfnissen grüner Start-ups hin – in städtischen-, dünn besiedelten-, und ländlichen Regionen. Dies unterstreicht die Notwendigkeit zweckorientierter Anpassungen innerhalb von UÖ, um systemische Pfadabhängigkeiten zu überwinden, die grüne Gründungsaktivitäten hemmen. Der dritte Artikel (*Kapitel 5*) vertieft diesen Gedanken, indem er alternative, zweckorientierte Indikatoren für Ökosysteme untersucht. Am Beispiel der Radverkehrs-

infrastruktur wird gezeigt, wie die physische Infrastruktur in traditionellen UÖ neu ausgerichtet werden kann, um grüne Start-ups zu unterstützen. Die Ergebnisse belegen einen signifikanten positiven Zusammenhang zwischen dem Anteil an Radinfrastruktur und der grünen Gründungsaktivität auf regionaler Ebene in Deutschland – in städtischen-, dünn besiedelten-, und ländlichen Regionen.

Insgesamt leisten die Ergebnisse dieser Dissertation einen Beitrag zur theoretischen Weiterentwicklung des UÖ-Konzepts, indem sie die Bedeutung zweck- und raumsensibler Anpassungen zur Förderung unterschiedlicher Formen unternehmerischer Aktivität aufzeigen. Darüber hinaus liefert die Dissertation praxisrelevante Erkenntnisse für regionale Entscheidungsträger, die Innovation zur Förderung von Wettbewerbsfähigkeit und ökologischer Nachhaltigkeit in der deutschen Volkswirtschaft vorantreiben möchten. Sie betont die Notwendigkeit regional angepasster Strategien sowie einer Neuausrichtung bestimmter traditioneller Elemente von UÖ – beispielsweise durch gezielte Investitionen in Radverkehrsinfrastruktur.

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List of Abbreviations

AIC	Akaike Information Criterion
AME	Average Marginal Effect
BBSR	Bundesinstitut für Bau-, Stadt- und Raumforschung
BMBF	Bundesministerium für Bildung und Forschung
BMVI	Bundesministerium für Verkehr und digitale Infrastruktur
CATI	Computer-Aided Telephone Interview
CCI	Cultural and Creative Industry
DG GROW	Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
EE	Entrepreneurial Ecosystem
ECF	European Cyclists' Federation
GDP	Gross Domestic Product
GEM	Global Entrepreneurship Monitor
GVIF	Generalized Variance Inflation Factor
IAB	Institut für Arbeitsmarkt- und Berufsforschung
ICC	Intraclass Correlation Coefficient
KfW	Kreditanstalt für Wiederaufbau
LRT	Likelihood Ratio Test
NCP 3.0	National Cycling Plan 3.0
NUTS	Nomenclature of Territorial Units for Statistics
PC	Principal Component
QoL	Quality of Life
RCI	Regional Competitiveness Index
R&D	Research and Development
SEE	Sustainable Entrepreneurial Ecosystem
SME	Small and Medium-sized Enterprise
TEA	Total Early-Stage Entrepreneurial Activity

UÖ	Unternehmerisches Ökosystem
URS 95	Unternehmensregister-System 95
VIF	Variance Inflation Factor
WZ	Wirtschaftszweige
ZEW	Zentrum für Europäische Wirtschaftsforschung

1 Introduction

1.1 Background to the research

As global markets become more competitive and environmental challenges like climate change intensify, entrepreneurship is increasingly called upon. It is seen not only as a driver of innovation for economic competitiveness but also as an agent capable of generating market-based solutions to reduce ecological footprints. Start-ups, defined as independent ventures less than eight years old that develop and commercialize new goods or services (Luger & Koo, 2005), are at the forefront of this. On the one hand, start-ups are key agents of innovation, an idea rooted in the seminal work of Schumpeter (1934). Particularly product innovations, defined as goods or services that are significantly improved in their characteristics or intended uses (Karlsson & Tavassoli, 2016), can enhance long-term economic competitiveness (Doğan, 2016; Reguia, 2014). On the other hand, start-ups also act as important market actors driving environmental change, especially green start-ups, which embed ecological sustainability into their core business models (Bergset & Fichter, 2015; Schaltegger & Wagner, 2011). Therefore, start-ups are particularly well-positioned to advance both competitiveness and ecological sustainability in advanced economies, largely because of their agility and greater willingness to take risks compared to more established firms (Kollmann & Pröpper, 2025).

While either innovation or environmental impact alone provides ample scope for a dissertation, examining both can reveal complementary pathways through which start-ups can contribute to economic competitiveness and ecological sustainability. Aside from the competitive advantages of product innovations (Doğan, 2016; Reguia, 2014), they can, under the right conditions, contribute to broader sustainability transitions through their ability to directly alter production and consumption patterns (Fukasaku, 2000) – though this is not inherently guaranteed (Ekins, 2010). Green start-ups, in turn, can foster competitiveness through eco-innovation and opening new markets for sustainable goods and services (Riandita et al., 2025). Recognizing the distinct yet overlapping roles of product-innovative and green start-ups – when they do not coincide within a single venture – enables policymakers to craft complementary strategies for economic competitiveness and market-based ecological sustainability.

From an economic geography perspective, the concept of entrepreneurial ecosystems (EEs) offers a valuable analytical lens to analyze how geographical conditions shape both product-innovative and green start-up activity. Originating from a broader shift in entrepreneurship studies to a more context-oriented perspective, EEs have emerged as a powerful conceptual tool through which to understand how locational characteristics shape start-up activity (Stam & Welter, 2020). EEs are defined as a set of interconnected (f)actors that foster high-growth entrepreneurship within a given territory (Spigel & Stam, 2018). These ecosystems typically encompass a variety of (f)actors (e.g., finance, human capital, knowledge, and physical infrastructure) that together create a fertile environment for entrepreneurship (Stam & Van de Ven, 2021). By shaping the opportunities and constraints entrepreneurs face, EEs influence the emergence, survival, and growth trajectories of start-ups (Stam & Spigel, 2016). Given their holistic and context-sensitive nature, EEs are particularly well-suited for analyzing the geographical conditions that contribute to product innovation in start-ups and facilitate green start-up activity.

Due to its globally underperforming start-up landscape, Germany provides a compelling context to explore these dynamics. Despite being one of the world's most advanced economies, its overall start-up scene is struggling to gain traction – though notable regional exceptions, such as Berlin, exist. In 2023, the country reported a historically high rate of start-up activity, as reflected in the total early-stage entrepreneurial activity[1] (TEA), yet it still ranked in the bottom third among nations participating in the Global Entrepreneurship Monitor (Sternberg et al., 2024). This suggests that while there is some level of entrepreneurial activity, Germany's overall start-up landscape still lags behind global leaders and faces significant barriers to growth. Meanwhile, many start-ups face difficulties in introducing novel products (Zimmermann, 2025), whilst the proportion of green start-ups has also decreased by 6 percentage points, from 35 % in 2023 to 29 % in 2024 (Fichter et al., 2024). In light of these challenges, strengthening Germany's ability to contribute to product innovation in start-ups and facilitate green start-up activity emerges as a critical strategy to maintain economic competitiveness while addressing market-based solutions to environmental issues.

However, these efforts are complicated by regional disparities across the country. Urban regions, with typically well-developed EEs, tend to benefit from well-established innovation networks, stronger institutional support, and better access to finance and talent, all of which contribute to a thriving start-up environment. In contrast, rural or economically weaker regions often face challenges such as inadequate infrastructure, institutional voids, and limited

[1] Although the total early-stage entrepreneurial activity (TEA) encompasses the percentage of the 18-64 population who are owner-manager of a new business, or start-up, it is not limited to start-up activity and also reflects nascent entrepreneurs (Sternberg et al., 2024).

resources, which impede start-up activity (Freire-Gibb & Nielsen, 2014; Tamásy, 2006). Due to these regional disparities, a regional approach is crucial to harness the strengths of more developed regions while also addressing the unique challenges faced by rural or economically weaker regions. Such a regional approach offers insights into how EEs can contribute to product innovation in start-ups and facilitate green start-up activity across diverse regions, ultimately enhancing Germany's position in an increasingly competitive and environmentally conscious global economy.

The main goal of this dissertation is twofold. It analyzes how regional EEs contribute to (1) product innovation in start-ups, on the one hand, and (2) facilitate green start-up activity, on the other hand. However, despite the increasing prominence of the EE concept in both academic and policy discourses, important research gaps continue to hinder a comprehensive understanding of these relationships. The following *Section 1.2* discusses these research gaps in detail, outlining the foundations on which the three empirical papers of this dissertation are built. The research questions presented in *Section 1.3* directly address these gaps and provide a structured framework for the dissertation. By shedding light on these underexplored areas, this dissertation seeks to advance theoretical knowledge in the EE literature, whilst offering insights for more differentiated and place-sensitive policy strategies.

1.2 Research gaps in the literature

This section outlines the key research gaps within the broader scope of the EE literature. These gaps are discussed in relation to product innovation (*Section 1.2.1*) and ecological sustainability (*Section 1.2.2*). Each identified gap serves as the foundation for one of the empirical papers, along with its corresponding research question presented in *Section 1.3*. Therefore, this section helps to clarify how this dissertation seeks to advance the theoretical understanding of EEs concerning both product innovation and ecological sustainability.

1.2.1 Product innovation

Academic and policy discourses have increasingly portrayed EEs as engines of innovation (Brown & Mason, 2017; Feld, 2020; Feldman et al., 2019; Spigel, 2017). However, limited attention has been given to the specific mechanisms through which these ecosystems support product innovation at the firm level. Existing research has predominantly focused on firm-level characteristics as the primary determinants of product innovations, thereby downplaying the potential influence of geographic or ecosystem-level factors (Beugelsdijk, 2007; Naz et al., 2015; Niebuhr et al., 2020; Sternberg & Arndt, 2001). While firm-level characteristics may be stronger predictors of innovation outcomes, the regional context remains crucial for understanding how such innovations in companies manifest and evolve differently across urban and rural regions (Johansson & Lööf, 2008). Johansson and Lööf (2008) have provided one insight into this issue, showing that in less dense and less diversified urban environments, innovative firms rely more on scientific innovation systems than in metropolitan regions. However, such a broad focus on regional dynamics overlooks the influence of key regional factors, for example, the availability of local skilled labour, networks, and infrastructure quality. These factors can shape whether and how firms engage in product innovation, influencing both their constraints and opportunities. This idea is well reflected in the concept of entrepreneurial ecosystems (EEs), yet it remains unclear how EEs influence product innovations in start-ups, and, most importantly, what differences exist between urban and rural regions. This research gap is addressed in the first research question (*Section 1.3*).

1.2.2 (Ecological) sustainability

In addition, EEs have traditionally been designed to stimulate economic growth and competitiveness. However, limited attention has been given to sustainable entrepreneurship (Theodoraki et al., 2022), defined as any entrepreneurial activity that incorporates ecological and social sustainability into the core business model (Schaltegger & Wagner, 2011). The predominant focus on economic scalability and growth in EEs has allowed environmental and social responsibilities to be sidelined. This is problematic, as it risks reinforcing patterns of environmental degradation, social inequality, and resource depletion, further exacerbating global sustainability challenges (Daly & Farley, 2011). In response to this, a novel wave of ecosystem research has emerged, so-called sustainable entrepreneurial ecosystems (SEEs) that aim to support sustainable entrepreneurship (Bischoff, 2021; DiVito & Ingen-Housz, 2021; Theodoraki et al., 2022; Volkmann et al., 2021). Conceptually, however, SEEs remain underdefined: there is no consensus on what distinguishes a sustainable ecosystem from a conventional EE beyond its re-orientation (Volkmann et al., 2021). Empirical evidence could help determine whether – and if so, how – EEs need to be transformed to better accommodate sustainable entrepreneurship. However, empirical research is lacking on the relationship between EEs and sustainability-oriented ventures, particularly green start-ups that focus on the ecological dimension of sustainability (Volkmann et al., 2021). This represents a clear research gap, which is addressed in the second research question (*Section 1.3*).

In light of the lack of sustainability in EEs, it is equally important to explore alternative pathways to traditional EEs that could facilitate green start-up activity. One example is the integration of environmentally responsible forms of physical infrastructure as one ecosystem-level component. In the conventional EE literature, physical infrastructure metrics are often centred around carbon-intensive transportation modes (see e.g., Audretsch et al., 2021; Leendertse et al., 2022). While these metrics do reflect economic connectivity, they largely overlook environmental impacts. For example, high reliance on motorways and air transport contributes to climate change, air pollution, and resource depletion (Hickman & Banister, 2019) – challenges that contradict the sustainability objectives of green start-ups. By contrast, environmentally responsible forms of physical infrastructure, such as cycling or public transportation networks, can reduce the ecological footprints of green start-ups while continuing to support their overall operations. However, virtually no study thus far has explored the relationship between cycling infrastructure and green start-ups, nor in the context of EEs. This research gap is addressed in the third research question (*Section 1.3*).

1.3 Research questions

This research addresses the gaps outlined in *Section 1.2* concerning the limited understanding of how EEs can contribute to product innovation in start-ups and facilitate green start-up activity. As discussed in *Section 1.1*, addressing both through a regional lens offers complementary pathways through which start-ups can advance competitiveness alongside ecological sustainability in Germany's economy. The overarching aim of this dissertation is to analyze how regional EEs can (1) contribute to product innovation in start-ups and, on the other hand, and (2) facilitate green start-up activity, on the other hand. To achieve this, the dissertation is structured around the following three research questions, each corresponding to a separate empirical paper:

I. How do entrepreneurial ecosystems (EEs) support product innovations in start-ups in urban and rural regions differently? (*Chapter 3*)

This paper addresses the first research gap by examining how different ecosystem-level components influence product innovation in start-ups across urban and rural regions. Although the region seems to be influential in how product innovation outcomes at the firm level manifest differently across urban and rural regions (Johansson & Lööf, 2008), the specific mechanisms through which EEs contribute to this remain unknown. The goal of this paper is to understand the main differences between urban and rural regions in how EEs contribute to product innovations in start-ups.

II. What is the relationship between entrepreneurial ecosystems (EEs) and green start-ups at the regional level? (*Chapter 4*)

This paper addresses the second research gap and investigates the (mis)alignment between EEs and green start-ups, questioning whether existing EEs sufficiently accommodate these kinds of ventures. Even though empirical evidence could help determine how EEs need to be transformed to better accommodate sustainability-oriented ventures such as green start-ups, such evidence is lacking (Volkmann et al., 2021). By assessing the (mis)alignments between EEs and green start-ups, the goal of this paper is to provide insights into where ecosystem-level transformation is most needed to better accommodate these kinds of ventures.

III. To what extent can cycling infrastructure facilitate green start-up activity at the regional level, and how is its effect amplified by the wider entrepreneurial ecosystem (EE)? (*Chapter 5*)

This paper addresses the third research gap by examining how cycling infrastructure, as one example of an alternative, underexplored metric of physical infrastructure in traditional EEs, is conducive to green start-up activity at the regional level. After all, it is equally important to explore alternative pathways to traditional EEs to facilitate green start-up activity in light of the lack of sustainability in EEs. In doing so, this paper further explores how the wider, complementary ecosystem – including networks, institutions, and knowledge resources – amplifies this effect. This is because physical infrastructure may act as a gateway, facilitating entrepreneurs’ access to the wider ecosystem of institutions and resources. Without such connections, infrastructure risks becoming an isolated asset rather than a meaningful driver of entrepreneurship (Wurth et al., 2022). The goal of this paper is to understand how cycling infrastructure is conducive to green start-up activity in the wider context of EEs.

1.4 Research design

This dissertation builds upon a quantitative research design. A quantitative approach enables the analysis of large-scale patterns and relationships across regions, offering generalizable insights into how EEs affect different entrepreneurial outcomes (Autio et al., 2014; Stam, 2015). Each empirical paper relies on regression-based techniques to identify statistically significant relationships between EE conditions and entrepreneurial outcomes. This approach enables the estimation of the independent effects on two key outcomes: product innovation and ecological sustainability as a core orientation in start-ups.

However, a quantitative research design also has limitations. These include the inability to fully capture the dynamic and non-linear nature of EEs and the inherent challenge of inferring causality. First, EEs are not static – they evolve over time as new institutions, actors, or technologies emerge (Alvedalen & Boschma, 2017; Cantner et al., 2021). For example, a new university program or the relocation of a major tech firm might significantly reshape the local ecosystem. Quantitative methods typically rely on cross-sectional or annual data, which may miss these important temporal dynamics. Second, relationships within EEs are, in reality, often non-linear; small changes in one part of the system can produce disproportionately large effects elsewhere, or vice versa. Standard regression models, however, assume linear relationships, potentially oversimplifying how ecosystems function. Third, there is an inherent challenge in inferring causality from quantitative, observational data. While regression-based methods can identify statistically significant associations (e.g., between ecosystem resources and green start-up rates), they do not, on their own, establish that one factor causes the other (Tacq, 2011). Unobserved variables, reverse causality, or complex feedback loops may be at play. Therefore, the findings must be interpreted as correlational, not causal.

Nonetheless, the methodological choice of this dissertation is a response to the growing call for more data-driven assessments of EEs at the regional level (Spigel et al., 2020). This call arises from two main challenges in existing EE research. The first is a problem of scale: much important data is aggregated at the national level, which obscures significant regional variation (Spigel et al., 2020). Despite the growing awareness of the role of contexts in entrepreneurship research, the role of geographical contexts has thus often been oversimplified in empirical studies (Welter, 2011). The second issue is related to the difficulties of gathering quantitative data on how EEs work. As hard as it is to define the types of entrepreneurship within EEs, “it is even harder to measure many of the actors and factors that make up strong EEs” (Spigel et al., 2020, p. 485). As such, this dissertation addresses the current lack of regionally grounded quantitative approaches in the EE literature.

1.4.1 Firm-level data

This dissertation draws on firm-level data from the IAB/ZEW Start-up Panel for its empirical chapters, accessed through a formal user agreement with the IAB and ZEW. The IAB/ZEW Start-up Panel is widely regarded as one of the most comprehensive sources of start-up data in Germany and is designed to support academic and policy-related research. The start-up panel is a cooperation project between the Institute for Employment Research (IAB), the Leibniz Centre for European Economic Research (ZEW), and the Verband der Vereine Creditreform. The annual survey is based on a random sample from the Mannheim Enterprise Panel (MUP). The panel is a longitudinal, representative dataset of individual start-up ventures that are tracked with computer-aided telephone interviews (CATIs) until they reach the age of eight years in Germany, stratified by industries and years of establishment. The data cover approximately 6,000 start-ups annually from 2008 to 2021. Its firm-level scope and panel structure enable robust econometric analyses over time. Furthermore, the data cover detailed information on characteristics of start-up ventures such as their product innovations and orientation towards ecological sustainability, making it a particularly well-suited secondary dataset for this dissertation.

1.4.2 Region-level data

Region-level data from a variety of sources is employed across the empirical chapters of this dissertation. However, a primary source is the INKAR database (Indikatoren und Karten zur Raum- und Stadtentwicklung) from the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR). This data provides a comprehensive set of open-access regional indicators relevant to spatial and urban development in Germany. INKAR offers regionally disaggregated data on a wide range of socio-economic, infrastructural, and institutional variables, making it an ideal source to capture the contextual conditions of EEs. Variables such as infrastructure quality, labour market characteristics, educational attainment, and economic performance are used in this dissertation to operationalize ecosystem-level components.

For the purpose of this dissertation, the analyses are conducted at the regional NUTS-3 level (Nomenclature of Territorial Units for Statistics), which corresponds to Germany's administrative districts. The NUTS classification system was developed by Eurostat, the statistical office of the European Union, to enable consistent, comparable regional statistics across member states. Originally, it consists of three hierarchical levels: NUTS-1 (major socio-economic regions), NUTS-2 (basic regions for the application of regional policies), and NUTS-3 (small regions for detailed diagnoses). However, to investigate the geographic properties of EEs and to measure relations between start-ups and their local ecosystems, "we need to disaggregate to a more fine-grained level of observation" (Hess et al., 2025, p. 2). Although most empirical studies still take a macro perspective, focusing on either the NUTS-1 or NUTS-2 level (see e.g., Leendertse et al., 2022), such macro perspectives neglect the micro-foundations of EEs (Roundy & Lyons, 2023). NUTS-3 regions, on the contrary, represent the most granular territorial level in the system, which is also consistently covered across different kinds of datasets, including those used in this dissertation. By incorporating a high level of regional granularity, this dissertation provides a more accurate reflection of local economic, social, and institutional conditions – thereby addressing a central shortcoming in existing EE research, namely the insufficient consideration of regional heterogeneity (Spigel et al., 2020).

1.5 Scientific contributions and structure

This dissertation contributes to the literature in three key ways.

First, this research contributes to the EE literature by exploring the mechanisms through which EEs contribute to product innovation at the firm level, with particular attention paid to the differences between urban and rural regions. By explicitly integrating the spatial dimension into the study of innovation, it also contributes to the broader regional innovation literature by showing the importance of place-specific conditions in shaping innovation outcomes. In shifting the analytical focus from a traditional firm-centric focus in innovation studies (see e.g., Beugelsdijk, 2007; Naz et al., 2015; Niebuhr et al., 2020; Sternberg & Arndt, 2001) to the wider EE context, this dissertation highlights the critical role of regional characteristics – such as local labour markets, network structures, and infrastructure – in shaping product innovation in start-ups. Ultimately, this work offers a more spatially grounded and context-sensitive understanding of innovation outcomes, which complements and extends existing firm-centric innovation models.

Second, this dissertation responds to the current lack of conceptual clarity around what differentiates SEEs from traditional EEs and addresses the lack of empirical evidence on how EEs are conducive to sustainability-oriented ventures such as green start-ups (Volkmann et al., 2021). By exploring the role of EEs in facilitating green start-up activity, this research contributes to both the EE and SEE literature. It expands the EE literature by demonstrating how traditional ecosystems can extend beyond growth objectives to actively support sustainability-oriented ventures, particularly green start-ups. At the same time, it advances the SEE literature by empirically identifying the specific ecosystem conditions that either enable such activities as they are or indicate where transformation is most needed to support them.

Third, this dissertation empirically investigates an alternative, novel metric of physical infrastructure in traditional EEs through the example of cycling as an enabler of green start-up activity. This shifts attention away from the established emphasis on carbon-intensive transportation systems in traditional EEs (see e.g., Audretsch et al., 2021; Leendertse et al., 2022). Moreover, this case illustrates how ecosystem measures can evolve to better align with green entrepreneurship. In doing so, this study contributes to both the EE and SEE literature. Specifically, it contributes to the EE literature by foregrounding the role of sustainable physical infrastructure – exemplified by cycling infrastructure – as a previously underexplored factor in enabling start-up activity in traditional ecosystems. At the same time, it advances the conceptual development of SEEs by identifying infrastructural conditions that facilitate green start-up activity as one subset of sustainable entrepreneurship. Thus, this research provides a new pathway for integrating ecological sustainability into ecosystem research and practice. As one of the first studies to examine the role of cycling infrastructure as a facilitator of start-up activity, this study also contributes to the broader entrepreneurship debate by highlighting the relevance of low-impact infrastructure for sustainability-oriented ventures, particularly green start-ups.

The remainder of this dissertation is structured as follows. *Chapter 2* provides a comprehensive theoretical framework on start-ups and the concept of EEs. *Chapters 3*, *4*, and *5* present the three empirical papers, each addressing one of the research questions outlined above. Finally, *Chapter 6* synthesizes the key findings, discusses their implications for theory and practice, and suggests directions for future research.

2 Theoretical Framework

This chapter presents the foundational theoretical concepts that support the dissertation as a whole. Each empirical chapter, however, has its own theoretical framework aligned with its specific research question. Accordingly, the goal of this chapter is to establish a theoretical basis for the key concepts without exploring the full theoretical depth found in each empirical study. Instead of providing an exhaustive framework, it seeks to clarify how central concepts are consistently defined throughout the dissertation.

2.1 Definition of start-ups

One persistent challenge in start-up research lies in the absence of a universally accepted definition of start-ups, particularly regarding age thresholds and operational criteria. For example, some scholars define start-ups as firms under five years of age (see e.g., Colombelli et al., 2016; Dumont et al., 2016), whereas others extend this threshold to include firms up to ten years old (Hirschfeld et al., 2024). This definitional ambiguity undermines the comparability of empirical studies and complicates efforts to derive generalizable insights. Such discrepancies lead to conceptual inconsistencies, where firms identified as start-ups in one study may be excluded in another, thus limiting the reliability of evidence-based policy design. In response to this fragmentation, Luger and Koo (2005) have advocated for a more standardized definition, proposing that start-ups be identified not solely by age but through a combination of three criteria: newness, active operation, and organizational independence. Adopting such a multidimensional definition can enhance theoretical clarity and improve the coherence of empirical research and policy applications across diverse contexts.

First, “newness” is the most common starting point. It refers to the creation of entirely new entities, excluding firms formed through mere changes in ownership, name, or legal status (Gries & Naudé, 2009). However, the age threshold remains a practical challenge, often driven by data availability. This dissertation uses a cut-off of eight years. This represents a pragmatic balance between conceptual alignment with established definitions (see e.g., Colombelli et al., 2016; Hirschfeld et al., 2024; Dumont et al., 2016) and the definition of start-ups in the secondary firm-level data, where firms are tracked until they reach the age of eight years old.

Second, “activity” is crucial to distinguish genuine economic actors from companies that only exist on paper, often established for legal purposes such as minimizing tax obligations. This is crucial because many registered firms never engage in trade (Schautschick &

Greenhalgh, 2016). Since inactive firms have a minimal economic impact, only those actively producing goods or services are considered start-ups in this dissertation (Luger & Koo, 2005).

Third, the criterion of "organizational independence" further refines the definition of start-ups adopted in this dissertation by excluding subsidiaries, spin-offs, and branches of incumbent ventures (Luger & Koo, 2005). These entities often benefit from the resources of their parent organizations, and their strategic motivations are typically aligned with corporate growth rather than entrepreneurial opportunity recognition. As such, their developmental trajectories, profiles, and innovation behaviours often diverge from those of independently founded ventures (Andersson & Klepper, 2013). Including them in start-up research would thus risk obscuring the mechanisms specific to genuinely new and autonomous firm formation.

2.1.1 Innovative start-ups

Generally, innovation is defined as the process of creating new or significantly improved products, processes, services, or business models that bring about value or address existing challenges (Schumpeter, 1934). Rooted in Schumpeter's (1934) definition, the OECD (2005) classifies four basic types of innovation: product, process, marketing (market), and organizational innovation. This dissertation focuses on product innovations.

Product innovations can contribute to regional economic competitiveness because of their associated firm-level productivity and ability to open up new markets (Doğan, 2016; Reguia, 2014). From an ecological perspective, product innovations can reduce environmental impact by altering production and consumption patterns (Tukker & Jansen, 2006). As Fukasaku (2000, p. 17) notes, ecological sustainability requires "changes in the nature of goods and services that are produced, as well as how they are produced, distributed and used." By definition, product innovations involve "the introduction of a good or a service that is new or significantly improved regarding its characteristics or intended uses, including significant improvements in technological specifications, components and materials, incorporated software, user friendliness or other functional characteristics" (Karlsson & Tavassoli, 2016, p. 1485).

Furthermore, product innovations, as well as other types of innovation, can vary along a continuum of novelty, ranging from incremental to radical forms. Incremental product innovations involve minor improvements or adaptations of existing products, typically relying on the recombination of established knowledge (Greve, 2007). These innovations tend to reinforce existing market structures and are often aligned with short- to medium-term competitiveness (Freixanet & Rialp, 2022). In contrast, radical product innovations represent a substantial departure from the existing knowledge base, often introducing fundamentally new product functionalities or disrupting established industries (Greve, 2007). They are typically riskier and more resource-intensive but can generate significant competitive advantages and structural shifts in markets (Acemoglu et al., 2022). Within the context of sustainability, both incremental and radical innovations offer pathways to sustainable competitive advantages by challenging existing non-sustainable practices through novel approaches (Chen et al., 2024). While radical innovations tend to produce more profound impacts (Chen et al., 2024), incremental innovations are essential for continuous improvement, market adoption, and the diffusion of sustainable practices. Therefore, this dissertation includes both types of product innovation in its empirical analysis to capture the full spectrum of innovation dynamics that drive competitiveness and potentially lay the groundwork for ecological sustainability.

2.1.2 Ecologically sustainable (green) start-ups

Green entrepreneurship, or ecopreneurship, has emerged as a distinct subfield within the broader domain of sustainable entrepreneurship (Demirel et al., 2019; Gast et al., 2017). Sustainable entrepreneurship refers to entrepreneurial activity that integrates economic, environmental, and social objectives in its core business model – often conceptualized through the triple bottom line (TBL) framework (see e.g., Elkington, 1997). The TBL approach, which emphasizes the simultaneous pursuit of profit (economic), planet (environmental), and people (social) objectives, has been foundational in framing sustainable entrepreneurship (Shepherd & Patzelt, 2011). This distinguishes sustainable entrepreneurship from conventional firms, for example, high-growth start-ups that often focus primarily on market expansion and profitability without embedding sustainability goals in their core operations (Muñoz & Cohen, 2018).

However, not all sustainability-oriented ventures address all three pillars equally. Green entrepreneurship, as a subset, is sustainability-oriented in the sense that it prioritizes environmental goals, but often without a strong social component (Schaper, 2016). This dissertation defines green entrepreneurship as “the process of identifying, evaluating, and seizing entrepreneurial opportunities that minimize a venture’s impact on the natural environment and therefore create benefits for society as a whole and for local communities” (Gast et al., 2017, p. 46). As such, green entrepreneurs seek to create market-based solutions to environmental problems by developing goods or services that reduce ecological footprints (Schaltegger & Wagner, 2011). These ventures may still achieve indirect social benefits, for example, through cleaner air, but their primary orientation is ecological rather than holistic in the TBL sense.

These distinctions, or subsets derived from the concept of sustainable entrepreneurship, have led to ongoing conceptual debates in the literature. Some scholars argue that environmental and social goals are inherently intertwined and that a truly sustainable enterprise must pursue both (Hockerts & Wüstenhagen, 2010). Others maintain that narrower forms of sustainability orientation, such as in green entrepreneurship, still play a critical role in sustainability transitions, especially in sectors where environmental challenges are most pressing (Schaltegger et al., 2018). This dissertation aligns with the last perspective, emphasizing that even in the absence of a fully integrated TBL approach, green entrepreneurship constitutes an essential driver of ecologically focused systemic change.

2.2 The concept of entrepreneurial ecosystems (EEs)

Emerging as part of a broader shift in entrepreneurship studies, the concept of EEs began to take shape in the early 1990s and 2000s. This shift moved away from individualistic, personality-driven research and embraced a more context-oriented perspective, emphasizing the role of social, cultural, and economic factors in shaping entrepreneurial processes (Nijkamp, 2003; Steyaert & Katz, 2004). The term “ecosystem” was first applied to entrepreneurship in a social science context following Moore's (1998) work, which highlighted how entrepreneurship emerges from a community of interconnected actors within a local environment (Freeman & Audia, 2006). Earlier work by Pennings (1982), Dubini (1989), Van de Ven (1993), and Bahrami and Evans (1995) had already touched on the idea of an “entrepreneurial environment”, or “ecosystem,” suggesting that regional economic and social factors play an important role in shaping entrepreneurial activity. Building on these foundations, the emphasis gradually shifted away from viewing the entrepreneur as the sole driver of value creation to recognizing the broader context in which entrepreneurship occurs (Zahra, 2007; Zahra et al., 2014).

The conceptualization of entrepreneurship as a collective, contextually embedded phenomenon has given rise to the concept of entrepreneurial ecosystems (EEs) (Stam & Welter, 2020). EEs are defined as “a set of interdependent actors and factors coordinated in such a way that they enable productive entrepreneurship within a particular territory” (Stam & Spigel, 2018, p. 1). Productive entrepreneurship is often associated with high-growth start-ups or scale-ups, which are regarded as key drivers of innovation, productivity, and economic growth

(Mason & Brown, 2014). The EE concept comprises ten interrelated (f)actors, encompassing both institutional arrangements, and tangible and intangible resources (Stam & Van de Ven, 2021; see Table 1). While EEs share conceptual overlaps with frameworks such as industrial districts, clusters, and innovation systems – each emphasizing the importance of contextual conditions – the EE concept is distinct in its entrepreneur-centric orientation, placing entrepreneurs at the core of ecosystem functioning (Rocha & Audretsch, 2022).

TABLE 2-1. Entrepreneurial ecosystem (EE) elements. Adapted from Stam & Van de Ven (2021).

Entrepreneurial ecosystem (EE) elements	**Definition**
Formal institutions	The rules and regulations in society
Entrepreneurial culture	The extent to which entrepreneurship is appreciated in society
Networks	The connectedness of businesses for new value creation
Physical infrastructure	Facilitator of labour mobility and the exchange of knowledge and ideas
Market demand	The availability of financial resources within the population to purchase goods and services
Intermediaries	Services that facilitate the creation, development, and growth of new businesses
Talent	The skills, knowledge, and experience held by individuals
Knowledge	Investments in knowledge (both scientific and technological)
Leadership	The presence of leaders who guide and direct collective action
Finance	The presence of financial means to invest in business activities

3 Empirical Paper

Meijering, B. & Schunder, T. (2025). Regional determinants of product innovations in start-ups across urban and rural regions in Germany.

Manuscript submitted to *Growth and Change*.

Abstract

In this study, we examine how region-level determinants, measured through entrepreneurial ecosystem (EE) elements, influence product innovation in high-tech start-ups across urban and rural regions differently in Germany. This study contributes to the scientific debate by integrating the EE concept into the regional innovation literature, uncovering whether and how regional conditions shape product innovations in start-ups differently in different locations. We differentiate between incremental and radical product innovations using firm-level data from the IAB/ZEW Start-up Panel during 2007-2014. The findings show that while certain region-level determinants may facilitate or hinder innovation, their impact varies depending on the type of region. Policies aimed at fostering product innovations in high-tech start-ups should be aligned with this.

Keywords: product innovation, start-ups, regions, Germany.

3.1 Introduction

Start-ups need to introduce product innovations, at least on occasion, to gain or maintain a competitive advantage, which holds the potential for sustainable regional economic growth (Lentz & Mortensen, 2008). However, research on this topic in rural regions remains limited (Audretsch & Feldman, 2004; Florida et al., 2018; Tavassoli et al., 2021). Innovation in general is often associated with urban regions due to resource availability in agglomeration economies (Meili & Shearmur, 2019). Yet, this does not explain how innovation occurs in both urban and rural regions, albeit to a lesser extent in the latter.

At first glance, regional disparities in innovation outcomes across urban and rural regions could point to distinct determinants, both at the firm- and the regional level. However, innovative firms exhibit similar characteristics, regardless of their location (Johansson and Lööf, 2008; Naz et al., 2015). In other words, firm-level determinants of product innovations seem to be similar across different regional contexts. Instead, the regional context can lead to variations in how product innovations emerge (Johansson and Lööf, 2008).

To date, however, the understanding of regional influences on firm-level product innovations remains limited. This can be primarily attributed to scholars arguing that it is rather firm characteristics than regional conditions that drive product innovations (Beugelsdijk, 2007; Naz et al., 2015; Niebuhr et al., 2020; Sternberg & Arndt, 2001). While this may be true, the region plays a more crucial role in explaining how these innovations manifest differently in different locations. Johansson and Lööf (2008) have provided one insight into this issue, showing that in less dense and less diversified urban environments, innovative firms rely more on scientific innovation systems than in metropolitan regions.

However, such a broad focus on regional dynamics overlooks the influence of key regional factors, such as the availability of local skilled labour, networks, and infrastructure quality. These factors can shape whether and how firms engage in innovation, influencing both their constraints and opportunities. This idea is well reflected in the concept of entrepreneurial ecosystems (EEs). The concept sheds light on how ten elements – such as human capital, finance, networks, support institutions, and cultural attitudes – foster innovative entrepreneurship in a given territory (Spigel & Stam, 2018). Thus far, it remains unclear how these individual elements influence product innovations in urban and rural start-ups. This study contributes to the scientific debate by integrating the EE concept into the regional innovation literature, providing a more nuanced understanding of how regional conditions shape product innovations in start-ups differently in urban and rural regions.

The objective of this study is to investigate how the influence of region-level determinants – measured by the EE elements – on product innovations in start-ups differs between urban and rural (NUTS-3) regions in Germany. We use start-up data from the IAB/ZEW Start-up Panel (2007-2014) in the high-tech industry. The high-tech industry is more than any other industry in Germany characterized by its innovative behaviour (Berger et al., 2019). In measuring product innovations, we differentiate between incremental and radical product innovations because of the different determinants found across them (Bellmann et al., 2018). Within our binary logit models, we incorporate two-way interaction effects between region-level determinants and a region type dummy (urban vs. rural). This approach allows us to understand the full complexity of how innovation unfolds in different locations and ensures that policies aimed at fostering product innovations in start-ups in rural and/or urban regions are well-aligned and effective (Castaldi, 2024).

The following section represents an overview of the literature. Hereinafter, the data, methods, results, and conclusion are discussed.

3.2 Literature

3.2.1 Defining product innovations

Product innovations can be categorized by their degree of novelty into exploitative and explorative types (Greve, 2007). Exploitative innovations use established technologies to create new products, building on a firm's existing knowledge (Li et al., 2008), while explorative innovations involve novel products based on new technological or market domains (Rosenkopf & Nerkar, 2001). From a firm's perspective, explorative innovations align with radical innovations (i.e., involving new knowledge creation) whereas exploitative innovations correspond to incremental innovations (i.e., advancing existing technologies) (Greve, 2007). However, theoretical definitions of radical innovations often focus on industry- or market-wide novelty rather than firm-specific perspectives, overlooking a firm's prior knowledge and the effort required to innovate (Garcia & Calantone, 2002). To us, a product's novelty is relative to the knowledge base of the firm. Thus, we define incremental innovations as those using techniques familiar to the firm, while radical innovations involve techniques new to the firm, regardless of their novelty to the broader market or industry.

3.2.2 The region: influential or not?

Innovation activity in firms points to significant disparities in innovation output across regions (Naz et al., 2015). These differences could be explained by region-level determinants that impact innovations. At the same time, firm-level determinants might also play a role (Sternberg, 2022). There is an extensive literature dealing with the determinants of product innovations in firms. Earlier studies consider product innovations primarily as a firm-level phenomenon that is determined by firm characteristics, for example, firm size, age, in-house R&D and workforce competencies (Ettlie & Rubenstein, 1987; De Jong & Vermeulen, 2006; Klette & Kortum, 2004). Their research can be traced back to the seminal work of Schumpeter (1934) who stated that innovative activity is caused by characteristics of the firm.

Quite another strand of research has shifted the focus to region-level determinants by investigating how a firm's innovation activities are affected by locational characteristics (Bode, 2004; De Beule & Van Beveren, 2012; Evangelista et al., 2001; Feldman & Audretsch, 1999; Sternberg, 2000). The underlying assumption here is that there must be some locational influence since, for example, urban regions show higher innovation rates than their rural counterparts. Locational advantages considered in urban regions are related to geographical proximity and agglomeration effects. Feldman (1994) argued that proximity enhances the ability of firms to exchange ideas, which can foster innovation, specifically among firms that rely on tacit knowledge because it can more easily spill over via frequent face-to-face interaction. In their study, De Beule and Van Beveren (2012) confirmed such a positive impact of agglomeration economies on firm-level innovation.

While the above-mentioned studies provide evidence in favour of an important role of the regional context, more recent studies call these findings into question. Beugelsdijk (2007) argued that for a true test of the relevance of regional factors, firm characteristics need to be controlled for. In line with this, various studies have combined firm-level data with information on the regional context in which the firm operates. Sternberg and Arndt (2001) showed that product innovations of small firms located in the Munich high-tech region are not influenced by the regional environment but by firm characteristics instead. Other studies also confirmed that firm-level determinants are more important than regional influences for product innovation (see e.g., López-Bazo & Motellón, 2018; Vega-Jurado et al., 2008). More recent studies even found that the composition effects of innovative firms in the region explain differences across regions in aggregated product innovation rates rather than regional factors measured by agglomeration effects (both localization and urbanization economies) (Niebuhr et al., 2020) and regional human capital endowments (Naz et al., 2015).

This debate has prompted some academics and practitioners to question whether geographical location matters after considering all potential firm-level determinants. However, regional conditions still play a crucial role in shaping the mechanisms through which product innovations emerge differently across regions (Johansson & Lööf, 2008; Naz et al., 2015). While innovative firms often share similar characteristics regardless of location, the regional context influences how innovation processes unfold differently across them (Johansson & Lööf, 2008). Despite this, research examining the broader regional environment and its role in fostering firm-level product innovations remains limited.

Firms operate within multifaceted contexts shaped by socioeconomic and institutional dimensions that drive entrepreneurial activity and innovation (Stam & Welter, 2020). One popular framework that provides insights into the regional context of entrepreneurship is the concept of entrepreneurial ecosystems (EEs). The concept consists of ten interdependent elements, including institutional arrangements and resource endowments that enable "productive" entrepreneurship within a given territory (Stam & Spigel, 2016). While the definition of "productive" entrepreneurship remains quite fuzzy, scholars often narrow this entrepreneurship down to "high-growth start-ups" or "scale-ups," claiming that this type of entrepreneurship is an important source of innovation (Mason & Brown, 2014; Stam & Spigel, 2018). Within the EE concept, the institutional arrangements component is captured by the formal institutions, culture and network elements. The resource endowment component is captured by the physical infrastructure, finance, leadership, talent, knowledge, intermediate services, and demand elements (Stam & Van de Ven, 2021). It must be acknowledged, however, that EEs are inherently complex systems where multiple elements interact to shape entrepreneurial outcomes (Wurth et al., 2022). However, by isolating individual elements – such as access to financial capital, networks, or regional leadership – researchers can better determine in the first place which key elements exert an influence on product innovation under what regional conditions. This granular approach helps avoid the risk of attributing innovation success to the ecosystem as a whole without understanding its key drivers across different regions.

3.3 Data and methods

3.3.1 Firm-level data

This study uses firm-level data from the IAB/ZEW Start-up Panel from 2007-2014 – previously known as the KfW/ZEW Start-up Panel – of the Centre for European Economic Research (ZEW). Starting from 2007 until 2014, start-ups were tracked about the degree of novelty of new products annually with computer-aided telephone interviews. Start-ups are defined as firms younger than eight years old that are legally independent firms run by at least one full-time entrepreneur[2]. We focus on the high-tech industry because it is the most innovative industry of all start-ups in the panel (Berger et al., 2019). The mean rate of product innovations during 2007-2014 was 0.412 across all start-ups, and 0.715 in high-tech start-ups. The high-tech industry is classified into sub-sectors via the WZ2008-codes represented in Table 3-1. Notably,

[2] De-merger foundations or subsidiaries are not included.

the average share of high-tech start-ups of all registered firms[3] in Germany during 2007-2014 in percentage was very low: 0.16%. In other words, we analyze quite a specific type of firm.

In the construction of our dataset, we use firm-level data of the latest reported innovation during 2007-2014 and reduce the dataset to one observation per firm. If no innovations were reported during 2007-2014, we use firm-level data from the latest year of their participation in the annual surveys up until 2014. The data reveal that most start-ups introduced a product innovation only once during this period. For example, among high-tech start-ups, 7.1% introduced incremental product innovations more than once, while 11.2% introduced radical product innovations more than once between 2007-2014. As most start-ups innovated only once during 2007-2014, collapsing the data to a single observation per firm avoids the potential bias of overemphasizing firms that innovate frequently. However, it is important to note that cross-sectional data carries the risk that the innovation behaviour is a reflection of a firm's location choice, leading to potential endogeneity. To deal with this, we use data on innovation activities after firm establishment, ensuring that the decision to innovate is not conflated with the initial choice of location. After the selection of high-tech start-ups, of the initial 14,016 start-ups, 6,045 high-tech start-ups remained in our dataset.

TABLE 3-1. Classification of the sub-sectors within the high-tech industry (survey wave 2008).

High technology industry	Abbreviation	WZ93-Code
Cutting-edge technology manufacturing	STW	23.30, 24.20, 24.41, 24.61, 29.11, 29.60, 30.02, 31.62, 32.10, 32.20, 33.20, 33.30, 35.30.
High-technology manufacturing	HTW	22.33, 24.11, 24.12-4, 24.17, 24.30, 24.42, 24.62-4, 24.66, 29.12-4, 29.31-2, 29.40, 29.52-6, 20.01, 31.10, 31.40, 31.50, 23.30, 33.10, 33.40, 34.10, 34.30, 35.20.
Technology-intensive services	TDL	64.2, 72 (w/o 72.2), 73.1, 74.2, 74.3.
Software	software	72.2

[3] According to the URS 95 system (“Unternehmensregister”).

Dependent variable

In this study, we use three dependent variables related to product innovations reported by high-tech start-ups between 2007-2014. In the annual panel surveys, start-ups were asked (i) whether they introduced a new product in the reference year and (ii) about the degree of innovation of new products (1 = tested and commonly useable techniques; 2 = new combination of old-established techniques; 3 = new techniques of third party enterprises; 4 = new, self-developed techniques). Our first dependent variable (INNOALL) represents product innovations in general. Hereinafter, we distinguish between incremental (INNO1ALL) and radical product innovations (INNO2ALL) to analyze whether they differ in the determinants from each other. Incremental product innovations were measured along tested and commonly useable techniques and/or new combinations of old-established techniques. Radical product innovations were measured along with new techniques of third-party enterprises and/or new, self-developed techniques.

Firm-level independent variables

The firm-level control variables were derived from the IAB/ZEW Start-up Panel (2007-2014) itself and are operationalized in Table 3-2. The determinants related to the firm that were included are in-house R&D expenditures, the firm size in number of employees and firm size in annual sales revenue. Vega-Jurado et al. (2008) found that in-house R&D is the main determinant of product innovations. Naz et al. (2015) showed that firm size and age also influence product innovations. However, in the context of our research, firm age appears to be an irrelevant control variable. This is because significant differences were observed only when comparing firms aged 25 years or older with younger firms (Naz et al., 2015), whereas the start-ups in our study are all a maximum of 8 years old.

The determinants related to the entrepreneur(s) that were included are educational attainment, industry experience, founding motivation, and whether the entrepreneur is a migrant. Human capital, measured by the educational attainment and industry experience of the founding team, is an important determinant for product innovations (Protogerou et al., 2017). Of course, the competencies of the workforce are also an important aspect of internal human capital (Avermaete et al., 2004), but due to a lack of firm-level data, these determinants were not included. Furthermore, the founding motivation is important for innovation, specifically in start-ups (Arvanitis & Stucki, 2012). Lastly, Brown et al. (2019) and Nathan and Lee (2013) found a significant positive relationship between migrant entrepreneurship and product innovation. Individuals who choose to migrate often possess qualities such as higher ambition, adaptability, and risk tolerance, which correlate with innovation capacity. While cultural diversity in teams overall is also an important determinant of innovation (Brixy et al., 2020; Ozgen et al., 2013), due to a lack of firm-level data, we were not able to include this.

TABLE 3-2. Measurement of firm-level independent variables.

Indicators	Measurement
Firm-related	
Firm size (employees)	Number of contracted employees[1] in the reference year
Firm size (revenue)	Annual sales revenue in the reference year
In-house R&D	Internal R&D expenditures in the reference year
Entrepreneur-related	
Foreign-born founder(s)	At least one of the founders is not German (1 = yes; 0 = no)
Educational attainment	Highest qualification of the founders (for teams: founder with the highest qualification) (1 = university/college degree; 0 = apprenticeship/professional school; master craftsman/public servant/vocational college)
Industry experience	Industry experience (for teams: founder with the longest experience) (1 = more than 7 years); 0 = 7 years or less[2])
Founding motivation	Intention for founding (1 = realization of a certain business idea; 0 = self-determined working; improper employment opportunities; escape from unemployment; encouragement by former employer; tax incentives[3])

[1] This includes full-time, part-time and slightly employed persons. Trainees, freelancers, apprentices, and leased employees were excluded.
[2] Industry experience was already a categorical variable in the original data.
[3] 2012 and 2013: additionally: 0 = higher income opportunities. 2014: (1 = realisation of certain business idea; 0 = self-determined working; escape from unemployment; improrper employment opportunities; higher income opportunities).

3.3.2 Region-level data

The region-level independent variables at the NUTS-3 level are measured by the EE elements and linked to firm-level data based on (i) the information of the NUTS-3 level of each start-up identifier and (ii) the respective reference year. Data for a few region-level determinants (i.e., formal institutions, networks, and knowledge) were unavailable at the NUTS-3 level. To address this, we used imputed data from the NUTS-2 level. Additionally, for years with missing data during 2007-2014 (see Table 3-9 in the Appendix), values from the closest available year were substituted.

Region-level independent variables

Within the institutional arrangements in EEs, formal institutions reflect the rules of the game in society (North, 1990). We measure this by the level of corruption, unaccountability and partiality of government services in the region based on the Quality of Government Index (RCI, 2016)[4]. Second, entrepreneurial culture reflects the degree to which entrepreneurship is valued in society (Stam & Spigel, 2016), which is measured by the number of self-employed per 100 members of the workforce. Although it is particularly the self-employment rate in science-based industries that fosters innovative entrepreneurship (Fritsch & Wyrwich, 2018), we only have data available on the self-employment rate of the workforce in general. Third, networks indicate the connectedness of businesses for new value creation and are measured by the share of SMEs in percentage with innovation cooperation activities (Stam & Spigel, 2016).

Within the resource endowments in EEs, physical infrastructure enables actors of the ecosystem to meet (Stam & Spigel, 2016). On the one hand, we measure it by the inhabitant-weighted straight-line distance to the nearest public transport stop and, on the other hand, by access to high-speed internet of 100 Mbit/s[5] among households. Both indicators facilitate connectivity between people, which is conducive to (innovative) entrepreneurship because it enables labour mobility and enhances the exchange of knowledge and information (Audretsch & Belitski, 2017). Second, we measure market demand by the GDP growth rate in percentage. Unlike GDP per capita, the GDP growth rate is a straightforward measure of economic momentum and serves as a broader proxy for market demand development, which enables larger economies of scale and gives further incentives to innovate (Audretsch, 2007). Third, talent is a reflection of the skills, knowledge, and experience possessed by individuals and measured by the share of the workforce employed in knowledge-intensive industries in percentage. Fourth, knowledge reflects the investments in (scientific and technological) knowledge creation, which is measured by intramural R&D expenditure as a percentage of GDP

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[4] We multiplied the z-scores of the quality and accountability as well as the impartiality of government services by −1. This ensures that all indicators consistently reflect the same conceptual direction, where higher scores indicate worse formal institutions (i.e., higher corruption, lower quality an accountability, greater partiality).

[5] Notably, data on 1000 Mbit/s is available from the year 2020 onwards.

(Stam & Van de Ven, 2021). Fifth, finance represents the presence of financial means for entrepreneurship and is measured as the share of start-ups in percentage that received external financial support in loans, venture capital or funds at least once between 2007-2014, mainly because financial support often extends beyond a single year. Sixth, leadership provides guidance for and direction of collective action and is often measured by the prevalence of innovation project leaders (Stam & Spigel, 2016). In a similar vein, we measure leadership through the EU funds in the 7th EU Research Framework Program in euros per member of the working-age population (Stam & Van de Ven, 2021). Seventh, intermediaries can substantially lower the barriers and increase the speed of new value creation, which are measured as indirect federal grants for projects supporting SMEs in their R&D activities in euros per member of the working-age population. These indirect federal grants are aimed at the development and strengthening of research infrastructures, as well as technology and innovation services such as incubators and accelerators (Stam & Van de Ven, 2021).

In addition to the EE elements, we controlled for the degree of urbanization measured by the share of land area occupied by settlements and transportation infrastructure. Agglomeration effects are strongly related to the degree of urbanization through the physical proximity of people and businesses, which improves the opportunity for the exchange of knowledge and ideas as critical inputs of innovation (Florida, 2002; Glaeser, 2011). We additionally controlled for urbanization economies using the share of the workforce employed in the creative and cultural industries (CCI) in percentage because this is positively associated with regional specialized diversification (Cicerone et al., 2021).

The classification of region types

To define urban and rural regions, we use so-called settlement-structural region types (in German: "siedlungsstrukturelle Kreistypen"), which is originally a 4-type classification of the BBSR (2021). However, we consolidated the classification into two types due to the limited availability of cross-sectional firm-level data for each of the original four categories. From the (back in the year 2020) 401 NUTS-3 regions, 200 regions are classified as „urban" and 201 regions as „rural". The classification of region types is based on three indicators:

- Proportion of population in large and medium-sized cities within the NUTS-3 region;
- Population density of the NUTS-3 region;

- Population density of the NUTS-3 region without consideration of large and medium-sized cities.

3.3.3 Model

Our primary aim is to understand how the effect of region-level determinants on the outcome (product innovations) changes with the type of region (1= urban; 0 = rural). Therefore, we use a binary logistic regression with two-way interaction effects. This approach is preferable to, for example, random effect modelling when the research goal is to understand specific conditional relationships directly rather than treating regional variability as a latent construct (Grilli & Rampichini, 2015). We control for firm-level determinants solely as main effects because previous studies have found that there are no major significant differences across different types of regions in the influence of firm-level determinants on product innovations (Johansson & Lööf, 2008; Naz et al., 2015).

We employ three binary logit models for each of our dependent variables. The three models estimate the odds of Y = 1, referring to a product innovation. Otherwise, the value 0 was assigned. The first model (INNOALL) examines any novel product innovation (aggregated measure), while the second (INNO1ALL) focuses on incremental innovations specifically. The third model (INNO2ALL) assesses radical innovations. The econometric model specification is as follows:

$$logit\big(Pr(Y_i = 1)\big) = \beta_0 + \sum_{j=1}^{7} \beta_j X_j + \sum_{k=1}^{13} \beta_k Z_k + \delta D + \sum_{k=1}^{13} \theta_k (Z_k \times D) \; (1)$$

where:

- $\text{logit}(\Pr(Y = 1))$ is the log-odds of the probability that the dependent variable Y = 1 for *i* dependent variables;
- β_0 is the intercept term;
- $\sum_{=1}^{7} \beta_j X_j$ represent the main effects for *j* firm-level independent variables;
- $\sum_{k=1}^{13} \beta_k \, Z_k$ represent the main effects for *k* region-level independent variables;
- δD is the region type dummy;
- $\sum_{k=1}^{13} \theta_k \, (Z_k \times D)$ represent the two-way interaction effects in which θ_k indicates how much the effect of Z_k for *k* region-level independent variables changes depending on whether *D* equals 1 or 0.

For interpretation of the two-way interaction effects, we calculate the average marginal effects (AMEs) with the following econometric model specification:

$$AME_{Z_k \times D} = \frac{1}{N}\sum_{k=1}^{N}(\theta_k \cdot \hat{y}_i \cdot (1 - \hat{y}_i)) \ (2)$$

where:

- θ_k is the coefficient for the interaction term $(Z_k \times D)$;
- $\hat{y}_i \cdot (1 - \hat{y}_i)$ represents the derivative of the logistic function (i.e., the slope of the predicted probability function). This is the factor that adjusts the change in probability due to a change in the interaction term;
- The formula sums this across all observations and then averages it by dividing;
- N, the number of observations, to get the AME.

3.3.4 Descriptive statistics

Table 3-3 represents the descriptive statistics. We log-transformed the continuous predictors beforehand because of skewness to the right. Log transformation can stabilize variance across observations, addressing heteroscedasticity, which is a violation of regression assumptions (Gelman, 2007). Formal institutions, networks and knowledge were already standardized as z-scores in the original RCI data before log transformation. The sample includes 6,045 high-tech start-ups of which 1,582 are based in rural and 4,463 in urban regions.

TABLE 3-3. Descriptive statistics.

Descriptive statistics	**Mean**	**St. Dev.**	**Min**	**Max**
INNOALL	0.688	0.463	0.000	1.000
INNO1ALL	0.367	0.482	0.000	1.000
INNO2ALL	0.428	0.495	0.000	1.000
In-house R&D	3.758	5.086	0.000	13.816
Firm size (sales revenue)	10.888	3.555	0.000	16.811
Firm size (employees)	0.677	0.927	0.000	5.476
Education	0.291	0.454	0.000	1.000

Industry experience	0.800	0.400	0.000	1.000
Foreign-born founder(s)	0.094	0.292	0.000	1.000
Founding motivation	0.407	0.491	0.000	1.000
Region type	0.738	0.44	0.000	1.000
Creativity	0.592	0.749	-1.435	2.418
Degree of urbanization	2.620	0.692	0.275	4.139
Formal institutions	-0.283	0.258	-1.022	0.003
Culture	2.375	0.219	1.005	2.984
Network	3.439	0.281	2.715	4.047
Accessibility	1.266	0.614	0.419	3.583
Digital infrastructure	4.127	0.414	-0.147	4.582
Market demand	1.473	1.009	-4.605	3.222
Intermediaries	0.002	1.433	-5.174	5.392
Talent	2.154	0.623	-1.204	3.986
Knowledge	0.896	0.519	-0.315	2.235
Leadership	1.509	1.737	-3.621	6.483
Finance	3.892	0.277	0.000	4.605

Table 3-3 indicates that 68.8% of all high-tech start-ups introduced at least one novel product during (INNOALL) 2007-2014 of which 36.7% introduced an incremental product innovation (INNO1ALL) and 42.8% introduced a radical product innovation (INNO2ALL). Figure 3-1 shows the spatial distribution of start-ups that introduced product innovations at least once during 2007-2014 as a share of 1 million members of the working-age population (mean rate during 2007-2014)[6]. Prior to the analysis, we controlled for multicollinearity with the generalized variance inflation factors (GVIF). The values (mean = 1.583) indicate no concerning level of multicollinearity (see Table 3-10 in the Appendix).

[6] Note that the measure of start-ups is relative to the working-age population. This can create a misleading impression, where some rural regions with a low working-age population and few start-ups may appear as product innovation hotspots on the map, despite not being actual hotspots in absolute numbers. This distortion also applies to Figures 5.1 and 5.2, which present the number of green start-ups as a percentage of all start-ups – regions with very few start-ups overall can show disproportionately high percentages.

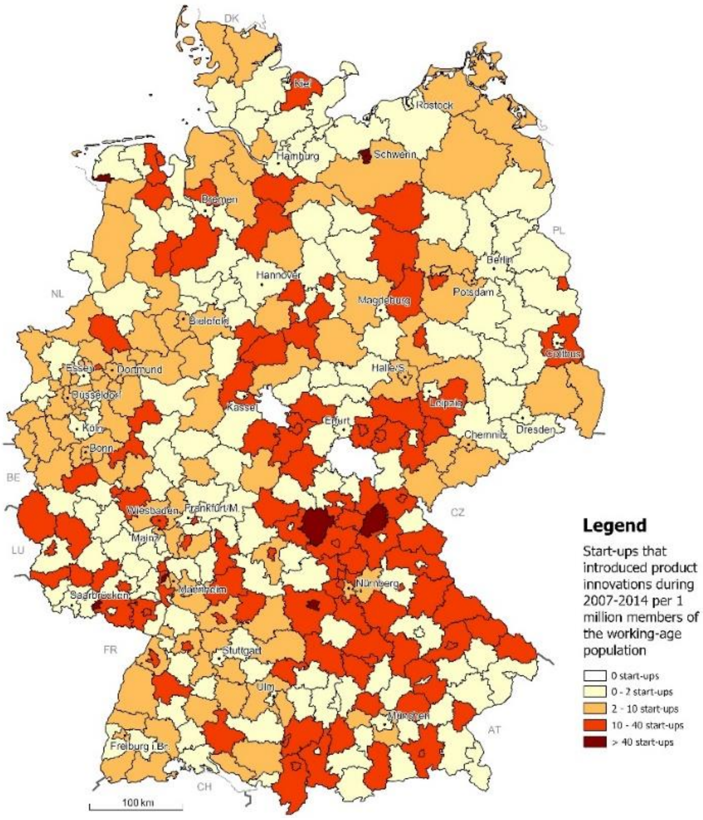

FIGURE 3-1. Start-ups within the high-tech industry that introduced product innovations at least once during 2007-2014 per 1 million members of the working-age population (mean rate between 2007-2014).

3.4 Results

At first, we examine the *t*-test to find significant differences in the mean of our dependent variables between urban and rural regions in Germany. The results in Table 3-4 show that for each dependent variable, the mean of the first group (rural) is significantly smaller than the mean of the second group (urban). This suggests that firm-level determinants as well as influential determinants at the level of the region might impact our dependent variables.

TABLE 3-4. Mean comparison across region types with the *t*-test.

t-test	Rural vs. urban	
Dependent variable	T-statistic	P-value
INNOALL	-4.633	0.000***
INNO1ALL	-3.231	0.001***
INNO2ALL	-3.050	0.002***

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

MODEL 1 (INNOALL): Product innovations			
Coefficients:	**Estimate**	**Odds ratio**	**Pr(>|z|)**
(Intercept)	0.707	2.028	0.381
Firm-level controls			
In-house R&D	**0.082*****	1.085	< 2e-16
Firm size (sales revenue)	0.003	1.003	0.640
Firm size (employees)	**0.059****	1.061	0.010
Education	**-0.114*****	0.893	0.005
Industry experience	**-0.095****	0.909	0.039
Foreign-born founder(s)	**0.151****	1.163	0.018
Founding motivation	**0.213*****	1.237	0.000
Region-level controls			
Region type dummy	0.003	1.003	0.998
Creativity	**0.152***	1.164	0.059
Degree of urbanization	0.106	1.112	0.108
Entrepreneurial ecosystem elements			
Formal institutions	0.092	1.097	0.486
Culture	-0.243	0.784	0.243
Network	-0.186	0.830	0.114
Accessibility	0.049	1.050	0.510
Digital infrastructure	-0.079	0.924	0.299

Market demand	0.017	1.017	0.586
Intermediaries	0.021	1.021	0.894
Talent	-0.003	0.997	0.954
Knowledge	**0.120***	1.128	0.097
Leadership	**-0.062***	0.940	0.070
Finance	**0.139***	1.150	0.087
Two-way interaction effects			
Region type X Creativity	-0.046	0.955	0.622
Region type X Degree of urbanization	-0.114	0.893	0.130
Region type X Formal institutions	-0.196	0.822	0.286
Region type X Culture	0.092	1.097	0.709
Region type X Network	**0.350****	1.419	0.017
Region type X Accessibility	-0.102	0.903	0.340
Region type X Digital infrastructure	0.058	1.060	0.696
Region type X Market demand	-0.002	0.998	0.956
Region type X Intermediaries	-0.058	0.944	0.711
Region type X Talent	**-0.120***	0.886	0.085
Region type X Knowledge	-0.006	0.994	0.949
Region type X Leadership	-0.006	0.994	0.867
Region type X Finance	**-0.241***	0.786	0.076
Model statistics			

AIC	6847.800	
Nagelkerke (Cragg & Uhler) Pseudo R^2	0.159	
Likelihood Ratio Test (Chisq)	727.860***	0.000
N	6045	

TABLE 3-5. Logit model of the dependent variable INNOALL.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

	MODEL 2 (INNO1ALL): Incremental product innovations			MODEL 3 (INNO2ALL): Radical product innovations		
Coefficients:	**Estimate**	**Odds ratio**	**Pr(>|z|)**	**Estimate**	**Odds ratio**	**Pr(>|z|)**
(Intercept)	0.333	1.395	0.669	**-1.880****	0.153	0.018
Firm-level controls						
In-house R&D	**0.013*****	1.013	0.000	**0.075*****	1.078	< 2e-16
Firm size (sales revenue)	**0.020*****	1.020	0.000	0.007	1.007	0.183
Firm size (employees)	**0.044****	1.045	0.031	**0.056*****	1.057	0.008
Education	**-0.112*****	0.894	0.003	-0.020	0.980	0.597
Industry experience	-0.012	0.988	0.777	0.025	1.025	0.571
Foreign-born founder(s)	-0.038	0.963	0.513	**0.150****	1.162	0.010
Founding motivation	-0.029	0.971	0.412	**0.279*****	1.322	0.000
Region-level controls						
Region type dummy	-0.492	0.611	0.669	0.773	2.167	0.511
Creativity	**0.162****	1.176	0.037	0.040	1.041	0.615
Degree of urbanization	0.059	1.060	0.362	0.020	1.021	0.756
Entrepreneurial ecosystem elements						
Formal institutions	0.086	1.090	0.510	-0.138	0.871	0.300
Culture	-0.207	0.813	0.309	0.013	1.013	0.948
Network	-0.159	0.853	0.163	-0.034	0.966	0.767
Accessibility	-0.018	0.982	0.802	0.111	1.118	0.127

Digital infrastructure	-0.082	0.921	0.248	0.032	1.033	0.659
Market demand	0.031	1.031	0.321	-0.027	0.973	0.384
Intermediaries	0.112	1.118	0.452	-0.108	0.897	0.472
Talent	-0.034	0.967	0.506	0.023	1.023	0.660
Knowledge	0.105	1.111	0.131	0.033	1.034	0.642
Leadership	-0.034	0.966	0.313	-0.031	0.970	0.375
Finance	0.073	1.076	0.378	**0.189****	1.208	0.029
Two-way interaction effects						
Region type X Creativity	-0.070	0.932	0.438	-0.040	0.961	0.664
Region type X Degree of urbanization	-0.044	0.957	0.545	-0.008	0.992	0.910
Region type X Formal institutions	-0.032	0.968	0.854	-0.019	0.981	0.916
Region type X Culture	0.129	1.138	0.586	0.069	1.072	0.775
Region type X Network	0.165	1.179	0.237	0.185	1.203	0.194
Region type X Accessibility	0.006	1.006	0.953	**-0.176***	0.839	0.090
Region type X Digital infrastructure	0.075	1.078	0.594	-0.077	0.926	0.592
Region type X Market demand	-0.040	0.961	0.276	0.050	1.051	0.181
Region type X Intermediaries	-0.122	0.886	0.416	0.072	1.074	0.635
Region type X Talent	-0.061	0.941	0.360	-0.060	0.942	0.374
Region type X Knowledge	0.004	1.004	0.959	-0.036	0.965	0.678
Region type X Leadership	-0.019	0.981	0.610	0.024	1.024	0.522
Region type X Finance	-0.095	0.909	0.472	-0.207	0.813	0.127

Model statistics				
AIC	7909.9		7556.400	
Nagelkerke (Cragg & Uhler) Pseudo R^2	0.025		0.160	
Likelihood Ratio Test (Chisq)	110.050***	0.000	767.81***	0.000
N	6045		6045	

TABLE 3-6. Logit models of the dependent variables INNO1ALL and INNO2ALL,

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

	MODEL 1 (INNOALL): Product innovations		MODEL 2 (INNO1ALL): Incremental product innovations		MODEL 3 (INNO2ALL): Radical product innovations	
Two-way interaction effects	**AME**	***P***	**AME**	***P***	**AME**	***P***
Creativity X Rural regions	**0.049***	0.051	**0.060****	0.039	0.014	0.617
Creativity X Urban regions	**0.033****	0.035	**0.034****	0.047	0.000	0.997
Employment density X Rural regions	0.034	0.100	0.022	0.364	0.007	0.757
Employment density X Urban regions	-0.002	0.834	0.006	0.648	0.004	0.718
Formal institutions X Rural regions	0.030	0.486	0.032	0.510	-0.047	0.300
Formal institutions X Urban regions	-0.033	0.415	0.020	0.645	-0.056	0.189
Culture X Rural regions	-0.079	0.241	-0.077	0.311	0.005	0.948
Culture X Urban regions	-0.048	0.259	-0.029	0.535	0.029	0.517
Network X Rural regions	-0.060	0.108	-0.059	0.165	-0.012	0.767
Network X Urban regions	**0.052***	0.058	0.002	0.941	0.053	0.067
Accessibility X Rural regions	0.016	0.512	-0.007	0.802	0.038	0.123
Accessibility X Urban regions	-0.017	0.491	-0.004	0.870	-0.023	0.381
Digital infrastructure X Rural regions	-0.026	0.300	-0.030	0.248	0.011	0.659
Digital infrastructure X Urban regions	-0.007	0.875	-0.003	0.951	-0.016	0.718
Market demand X Rural regions	0.006	0.585	0.011	0.321	-0.009	0.384
Market demand X Urban regions	0.005	0.477	-0.004	0.640	0.008	0.262

Intermediaries X Rural regions	0.007	0.894	0.041	0.441	-0.037	0.466
Intermediaries X Urban regions	**-0.012****	0.017	-0.004	0.493	**-0.013****	0.011
Talent X Rural regions	-0.001	0.954	-0.013	0.506	0.008	0.660
Talent X Urban regions	**-0.039*****	0.007	**-0.035****	0.025	-0.013	0.388
Knowledge X Rural regions	**0.039***	0.093	0.039	0.132	0.011	0.643
Knowledge X Urban regions	**0.036****	0.028	**0.041****	0.025	-0.001	0.953
Leadership X Rural regions	**-0.020***	0.075	-0.013	0.310	-0.011	0.373
Leadership X Urban regions	**-0.022*****	0.000	**-0.020*****	0.000	-0.002	0.650
Finance X Rural regions	**0.045***	0.086	0.027	0.379	**0.065****	0.029
Finance X Urban regions	-0.032	0.351	-0.008	0.830	-0.007	0.861

TABLE 3-7. Average marginal effects (AMEs) of the two-way interaction effects.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.0$.

Product innovations

Table 3-5 shows that product innovations in high-tech start-ups are significantly and positively influenced by firm-level determinants associated with in-house R&D, firm size (number of employees), the entrepreneur's founding motivation related to the realization of a certain business idea, and the presence of at least one foreign-born entrepreneur in the founding team. The latter confirms the findings of Brown et al. (2019) and Nathan and Lee (2013) that, aside from cultural diversity external to the firm (Niebuhr, 2010; Prenzel et al., 2024) and within the entire firm (Brixy et al., 2020; Ozgen et al., 2013), there also exists a significant positive relationship between migrant entrepreneurship and product innovativeness. Firm size in sales revenue does not have a significant influence on product innovations (see Table 3-5). Surprisingly, founding teams with at least one founder with a university degree and/or with more than seven years of industry experience have a significant and negative influence on product innovations.

The average marginal effects (AMEs) represent the effects of the region-level determinants for each region type in Table 3-7. We find evidence that various region-level determinants significantly influence product innovations, but their effect varies depending on the region type, aligning with the findings of Johansson and Lööf (2008). The share of the workforce employed in creative and cultural industries and the regional knowledge measured by the intramural R&D expenditure as a percentage of GDP have a stronger positive effect on the probability of product innovations in rural than in urban regions. However, regional leadership has a stronger negative effect on the probability of product innovations in urban than in rural regions.

Furthermore, we also find that some region-level determinants have a significant effect on product innovations in one type of region but not in the other. Talent within the knowledge-intensive industries and regional intermediaries are both associated with a decrease in the probability of product innovations in urban regions, with no significant effect observed in rural regions. Networks, as measured by the share of SMEs with innovative cooperation activities, are associated with an increase in the probability of product innovations in urban regions, whereas the effect is not significant in rural regions. On the contrary, we find that finance is associated with an increase in the probability of product innovations in rural regions, whereas this effect is not significant in urban regions.

However, there are different types of product innovations: incremental and radical product innovations and previous research found that for each type, different determinants are at play (Bellmann et al., 2018). The next sections discuss the determinants of each type of product innovation, also in relation to the literature.

Incremental

Similar to product innovations in general in Table 3-5 (model 1), incremental product innovations are significantly and positively influenced by firm-level determinants associated with firm size (number of employees) and in-house R&D, whereas they are negatively influenced by founding teams with at least one founder with a university/college degree (see Table 3-6). However, as opposed to product innovations in general (model 1), firm size (sales revenue) is significant and positively influences incremental product innovations, whereas industry experience and founding motivation are insignificant.

With regard to the AMEs for incremental product innovations in Table 3-7, we find a distinct urban-rural divide in the effects of significant region-level determinants. Similar to product innovations in general (model 1), the significant AMEs in Table 3-7 reveal that the share of the workforce employed in creative and cultural industries has a stronger positive effect on the probability of incremental product innovations in rural than in urban regions.

However, the other significant region-level determinants influence incremental product innovations in start-ups solely in one type of region. Both regional leadership and talent in the knowledge-intensive industries are associated with a decrease in the probability of incremental product innovations in urban regions, with no significant effect observed in rural regions. Too much centralization and leadership in innovation processes can potentially limit the scope of smaller, incremental innovations in favour of larger, more disruptive innovations (Chesbrough, 2003). Also, knowledge-intensive industries are more likely to engage in radical innovation because of their focus on R&D and new technologies (Frenken & Boschma, 2007), which can crowd out incremental innovations. Simultaneously, our findings show that knowledge, as measured by intramural R&D expenditures as a percentage of GDP, is associated with an increase in the probability of incremental product innovations in urban regions, with no significant effect observed in rural regions. Although Beck et al. (2016) found no significant effect of policy-induced external R&D on incremental innovation, intramural R&D expenditures, on the contrary, focus on improving existing products, processes, or technologies and can positively impact incremental product innovations, as shown by our findings (see Table 3-7).

Put together, quite some region-level determinants significantly impact incremental product innovations in start-ups in urban regions, as opposed to Bellmann et al. (2018), who did not find any significant region-level determinants in incremental innovations. However, their study was based on the regional level in Germany overall (Bellmann et al., 2018). At the same time, we find that the region-level determinants that significantly influence incremental product innovations in start-ups fade into insignificance in rural regions. However, the share of the workforce employed in creative and cultural industries is the key region-level determinant of incremental product innovations in start-ups in rural regions, with an even stronger positive effect than in urban regions.

Radical

Similar to product innovations in general in Table 3-5 (model 1), radical product innovations are significantly and positively influenced by firm-level determinants associated with in-house R&D and the firm size (number of employees), the founding motivation related to the realization of a certain business idea, and a founding team with at least one foreign-born entrepreneur. Interestingly, the level of education and industry experience are both insignificant, whereas in product innovations in general (model 1), they are both significant and in incremental product innovations (model 2), the level of education is significant. We also find that firm size (sales revenue) is not significant, whereas this indicator is significant and positively associated with incremental product innovations in Table 3-6 (model 2).

As opposed to product innovations in general (model 1) and incremental product innovations (model 2), radical product innovations are significantly influenced by region-level determinants in one type of region, whereas they fade into insignificance in the other type of region, as represented by the AMEs in Table 3-7. The share of start-ups that received financial support between 2007-2014 increases the probability of radical product innovations in rural regions, with no observed significant effect in urban regions. Tödtling and Trippl (2005) argue that rural regions are often characterized by “peripheral innovation systems,” where external resources like financial support play a critical compensatory role in overcoming resource constraints to innovate. On the contrary, intermediaries decrease the probability of radical product innovations in urban regions. Belitz and Lejpras (2016) found that such indirect federal grants are less oriented towards radical product innovations in SMEs. However, the relationship is not significant in rural regions, which implies that they are not significantly in favour of one type of product innovation in rural settings.

Interestingly, the findings in Table 3-7 show that there are not many significant region-level determinants, as opposed to Bellmann et al. (2018) in their study on radical innovations in German regions. There are even no significant positive effects of the region-level determinants on radical product innovations in urban regions. However, Asheim and Isaksen (2002) highlight that urban regions act as hubs for external linkages, implying that firms may draw more from global or inter-regional connections, which diminishes the importance of region-level determinants. Simultaneously, in regions with well-developed ecosystems, region-level determinants could lose marginal value because firms already have access to what they need (Brown & Mason, 2017). Also, Rodríguez-Pose and Crescenzi (2008) argue that in highly developed urban regions, firms often rely on diverse and interdependent resources, diminishing the measurable impact of any single region-level determinant.

3.4.1 Robustness check

To assess the robustness of our findings, we test whether the inclusion of firm-level determinants (such as firm size and in-house R&D) in the interaction term with the region type dummy would have improved our initial models with the Likelihood Ratio Test (LRT). Even though the choice of our model builds on the findings of Johansson & Lööf (2008) and Naz et al. (2015), who have found that innovative firms have similar characteristics irrespective of where they are located, we should take into account two considerations. First, the firms, regions and determinants we have investigated differ from previous empirical studies above, mostly due to data availability. Second, firms are nested in regions, meaning their features are often influenced by their direct surroundings, pointing at differences across region types (Stam & Welter, 2020). Building on this, we should test if our chosen firm-level determinants, indeed, do not influence product innovations differently across different types of regions. The null hypothesis of the LRT is that the reduced model (without firm-level interaction terms) is sufficient to explain the data, meaning that the additional interaction effects with firm-level determinants do not significantly improve the model fit. To test this, we use the following econometric specification for the complex model:

$$logit\big(Pr(Y_i = 1)\big) = \beta_0 + \sum_{j=1}^{7} \beta_j X_j + \sum_{k=1}^{13} \beta_k Z_k + \delta D + \sum_{k=1}^{7} \theta_j \big(X_j \times D\big) + \sum_{k=1}^{13} \theta_k (Z_k \times D)$$

(3)

where, newly to specification (1):

- $\sum_{k=1}^{7} \theta_j (X_j \times D)$ represent the two-way interaction effects in which θj indicates how much the effect of Xj for j firm-level independent variables changes depending on whether D equals 1 or 0.

Table 3-8 represents the Likelihood Ratio Test (LRT) of the initial model (reduced) as used in our analysis for each dependent variable in comparison to the complex model with two-way interaction effects between the region type dummy and (1) firm-level determinants as well as (2) region-level determinants. For INNOALL, INNO1ALL, and INNO2ALL we find no significant improvement in the LRT for the complex model. Based on this, our initial models as used in the analyses are preferred.

Likelihood Ratio Test (LRT)	**Reduced vs. complex model with full interaction terms**	
Dependent variable	Deviance	Pr(>Chi)
INNOALL	3.820	0.800
INNO1ALL	3.766	0.806
INNO2ALL	5.821	0.561

TABLE 3-8. Likelihood Ratio Test of the reduced vs. complex model.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

3.5 Discussion and Conclusion

This study investigated how the influence of region-level determinants (i.e., EE elements) on product innovations in high-tech start-ups differs between urban and rural regions in Germany. We differentiated between the novelty of product innovations (incremental and radical) and used binary logit models with two-way interaction effects between region-level determinants and a region-type dummy. The contribution is the integration of the EE concept into the regional innovation literature, providing a more nuanced understanding of how regional conditions shape product innovations in start-ups differently in urban and rural regions.

The findings show that the geographical location still matters in influencing product innovations in start-ups, in contrast to other studies (see e.g., Beugelsdijk, 2007; Naz et al., 2015; Niebuhr et al., 2020; Sternberg & Arndt, 2001). However, its influence is not uniform; rather, it is deeply embedded in the specific regional context. Policymakers should recognize that while certain region-level determinants may facilitate or hinder innovation, their impact varies depending on the structural characteristics of each region. For example, external financial capital is a critical element in fostering radical product innovations in rural regions, with no observed significant effect in urban regions. While start-ups in rural regions may still face structural disadvantages compared to their urban counterparts, the findings show that there are still opportunities for regional policymakers to foster innovation in rural start-ups. However, policies aimed at fostering product innovations in rural start-ups clearly need to be differently aligned from those in urban regions. In other words, there is no "one-size-fits-all" approach.

There are several limitations to our study. At first, the data in this study was quite outdated – although the data on product innovation was only collected between 2007-2014. Future research with updated data could provide further insights into how evolving economic, technological, and policy environments continue to shape innovation dynamics across urban and rural regions. Understanding these nuances is crucial for designing innovation policies that are effective in either urban or rural regions by accounting for regional specificities rather than applying a "one-size-fits-all" approach. In addition, we were not able to control for omitted variable bias at the region level because there were regions with just a few observations. Utilizing larger datasets could help capture such unobserved heterogeneity. Also, we were not able to control for firm-level fixed effects because we limited the panel data to cross-sectional data. Future research could control for firm-level fixed effects and examine the impact on the significance of our region-level determinants. In a similar vein, future research could investigate if the influence of region-level determinants changes with additional innovations introduced during the life course of firms. Also, due to a lack of region-level data for many indicators before the year 2007, we were not able to include spatial lags, and, in addition, some of our region-level indicators were flawed due to a lack of NUTS-3 data or missing years in the data. Lastly, while some region-level determinants significantly influence product innovation in isolation, depending on the regional context, examining EEs through the interdependencies between their elements may provide a more comprehensive approach for future regional innovation studies. After all, EEs function as “ecosystems” precisely because of the mutual interactions among their elements (Wurth et al., 2022), which shape entrepreneurship and innovation (Spigel & Stam, 2018). Future research could explore how these interdependencies foster firm innovation and whether a significant urban-rural divide exists, given that ecosystems are typically more developed in urban regions.

Disclosure statement

The authors declare no potential conflict of interest.

3.6 Appendix

TABLE 3-9. Operationalization of region-level determinants.

Indicators	**Measurement in time <>**	**NUTS-level**	**Source and data availability <>**
Degree of urbanization *(control variable)*	The area of settlement and transport land as a share of total land (in hectares) <2007-2014>.	NUTS-3	Ongoing spatial monitoring of the BBSR (2008-2023);
Creativity *(control variable)*	The % of employees in the creative and cultural industries of the total workforce <2008-2014>.	NUTS-3	Ongoing spatial monitoring of the BBSR (2008-2023);
Entrepreneurial ecosystem elements			
Formal institutions	Quality of Government Index based on the level of corruption, unaccountability and impartiality <2013>.	NUTS-2	European Quality of Institutions Index and DG Region own computations in the RCI (2016[7])

[7] The indicators as used above were not available in the RCI 2013. The following RCI published in 2019 has data for the year 2017 on the same indicators.

Entrepreneurial culture	The % of self-employed per 100 members of the workforce <2007-2014>.	NUTS-3	Ongoing spatial monitoring of the BBSR (2000-2023);
Networks	The % of SMEs with innovation co-operation activities <2012>.	NUTS-2	Regional Innovation Scoreboard (DG GROW) in the RCI (2016[8])
Physical infrastructure	Inhabitant-weighted straight-line distance to the nearest public transport stop with at least 20 departures per day <2016>.	NUTS-3	Ongoing spatial monitoring of the BBSR (2016-2022);
Digital infrastructure	The % of households with high-speed internet of 100 Mbit/s <2017>.	NUTS-3	BMVI (2017-2023)
Market demand	Rate of change in GDP compared to the previous year in % <2007-2014>.	NUTS-3	Ongoing spatial monitoring of the BBSR (2000-2023)
Intermediaries	Indirect federal grants for R&D projects supporting SMEs in euros per member of the working-age population <2008–2014>.	NUTS-3	BMBF (2008-2014)
Talent	The share of the workforce employed in knowledge-intensive industries in % <2009-2014>.	NUTS-3	Ongoing spatial monitoring of the BBSR (2009-2023);
Knowledge	Intramural R&D expenditure as % of GDP <2015>.	NUTS-2	Eurostat, Regional Science and Technology Statistics in the RCI (2019[9])
Leadership	EU funds in the 6th and 7th EU Research Framework Program in euros per member of the working-age population <2007-2014>.	NUTS-3	EU-Kommission, Vertragsdatenbank zur Beteiligung am EU-Forschungsrahmenprogramm (2002-2014)
Finance	The share of start-ups that received external financial support in loans, venture capital, or funds at least once in % <2007-2014>.	NUTS-3	IAB/ZEW Start-up Panel (2008-2015)

[8] The indicator as used above were not available in the RCI 2013 in "Business Sophistication." The following RCI published in 2019 has data for the year 2017 on this indicator.
[9] Previous RCI published in 2016 and 2013 have missing data for this indicator.

TABLE 3-10. Generalized variance inflation factor (GVIF).

	GVIF	**df**	**GVIF^(1/(2*df))**
In-house R&D	1.151	1.000	1.073
Firm size (sales revenue)	1.320	1.000	1.149
Firm size (employees)	1.369	1.000	1.170
Education	1.072	1.000	1.036
Industry experience	1.048	1.000	1.024
Foreign-born founders	1.020	1.000	1.010
Founding motivation	1.070	1.000	1.035
Region type	2.143	1.000	1.464
Creativity	2.913	1.000	1.707
Degree of urbanization	1.380	1.000	1.175
Formal institutions	1.785	1.000	1.336
Culture	1.936	1.000	1.391
Network	1.200	1.000	1.096
Accessibility	3.366	1.000	1.835
Digital infrastructure	2.201	1.000	1.483
Market demand	1.025	1.000	1.012
Intermediaries	1.358	1.000	1.165
Talent	1.469	1.000	1.212
Knowledge	1.513	1.000	1.230
Leadership	1.885	1.000	1.373
Finance	1.025	1.000	1.013

3.7 References

Acs, Z. J., & Audretsch, D. B. (2005). Entrepreneurship and innovation (No. 2105). Papers on Entrepreneurship, Growth and Public Policy.

Adner, R. (2017). Ecosystem as structure: An actionable construct for strategy. Journal of Management, 43(1), 39-58.

Arvanitis, S., & Stucki, T. (2012). What determines the innovation capability of firm founders? Industrial and Corporate Change, 21(4), 1049-1084.

Asheim, B. T., & Isaksen, A. (2002). Regional innovation systems: The integration of local 'sticky' and global 'ubiquitous' knowledge. The Journal of Technology Transfer, 27(1), 77-86.

Audretsch, D. B. (2007). Entrepreneurship capital and economic growth. Oxford Review of Economic Policy, 23(1), 63-78.

Audretsch, D. B., & Belitski, M. (2017). Entrepreneurial ecosystems in cities: Establishing the framework conditions. The Journal of Technology Transfer, 42, 1030-1051.

Audretsch, D. B., & Feldman, M. P. (2004). Knowledge spillovers and the geography of innovation. In Handbook of Regional and Urban Economics (Vol. 4, pp. 2713-2739). Elsevier.

Avermaete, T., Viaene, J., Morgan, E. J., Pitts, E., Crawford, N., & Mahon, D. (2004). Determinants of product and process innovation in small food manufacturing firms. Trends in Food Science & Technology, 15(10), 474-483.

Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR). (2021). Indikatoren und Karten zur Raum- und Stadtentwicklung: INKAR. Retrieved November 17, 2021, from https://www.inkar.de/.

Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR). (2021). Raumgliederungen des BBSR. Retrieved September 9, 2021, from https://www.bbsr.bund.de/BBSR/DE/forschung/raumbeobachtung/Raumabgrenzungen/raumabgrenzungen-uebersicht.html.

Beck, M., Lopes-Bento, C., & Schenker-Wicki, A. (2016). Radical or incremental: Where does R&D policy hit? Research Policy, 45(4), 869-883.

Belitz, H., & Lejpras, A. (2016). Financing patterns of R&D in small and medium-sized enterprises and the perception of innovation barriers in Germany. Science and Public Policy, 43(2), 245-261.

Bellmann, L., Evers, K., & Hujer, R. (2018). Regional and firm-specific effects on innovations using multi-level methods. The Annals of Regional Science, 61, 319-349.

Berger, M., Egeln, J., & Gottschalk, S. (2019). Innovative Unternehmensgründungen in Deutschland: Auswertungen aus dem IAB/ZEW Gründungspanel (No. 13-2019). Studien zum deutschen Innovationssystem.

Beugelsdijk, S. (2007). The regional environment and a firm's innovative performance: A plea for a multilevel interactionist approach. Economic Geography, 83(2), 181-199.

Bode, E. (2004). The spatial pattern of localized R&D spillovers: An empirical investigation for Germany. Journal of Economic Geography, 4(1), 43-64.

Boschma, R. A., & Fritsch, M. (2009). Creative class and regional growth: Empirical evidence from seven European countries. Economic Geography, 85(4), 391-423.

Bremner, R. P., Eisenhardt, K. M., & Hannah, D. P. (2017). Business ecosystems. In Collaborative Strategy (pp. 215-223). Edward Elgar Publishing.

Brixy, U., Brunow, S., & D'Ambrosio, A. (2020). The unlikely encounter: Is ethnic diversity in start-ups associated with innovation? Research Policy, 49(4), 103950.

Brown, J. D., Earle, J. S., Kim, M. J., & Lee, K. M. (2019). Immigrant entrepreneurs and innovation in the US high-tech sector (No. c14103). Cambridge, MA, USA: National Bureau of Economic Research.

Brown, R., & Mason, C. (2017). Looking inside the spiky bits: A critical review and conceptualization of entrepreneurial ecosystems. Small Business Economics, 49, 11-30.

Castaldi, C. (2024). The geography of urban innovation beyond patents only: New evidence on large and secondary cities in the United States. Urban Studies, 61(7), 1248-1272.

Chesbrough, H. (2003). The logic of open innovation: Managing intellectual property. California Management Review, 45(3), 33-58.

Cicerone, G., Crociata, A., & Mantegazzi, D. (2021). Cultural and creative industries and regional diversification: Does size matter? Papers in Regional Science, 100(3), 671-688.

Cooke, P. (2008). Regional innovation systems: Origin of the species. International Journal of Technological Learning, Innovation and Development, 1(3), 393-409.

De Beule, F., & Van Beveren, I. (2012). Does firm agglomeration drive product innovation and renewal? An application for Belgium. Tijdschrift voor Economische en Sociale Geografie, 103(4), 457-472.

De Jong, J. P., & Vermeulen, P. A. (2006). Determinants of product innovation in small firms: A comparison across industries. International Small Business Journal, 24(6), 587-609.

Delgado, M. (2020). The co-location of innovation and production in clusters. Industry and Innovation, 27(8), 842-870.

Ettlie, J. E., & Rubenstein, A. H. (1987). Firm size and product innovation. Journal of Product Innovation Management, 4(2), 89-108.

European Commission. (2016). European Regional Competitiveness Index 2016. Directorate-General for Regional and Urban Policy. Retrieved from https://ec.europa.eu/regional_policy/information-sources/maps/regional-competitiveness/2016_en.

European Commission. (2019). The European Regional Competitiveness Index 2019. Directorate-General for Regional and Urban Policy. Retrieved from https://ec.europa.eu/regional_policy/en/information/publications/working-papers/2019/the-european-regional-competitiveness-index-2019.

Evangelista, R., Iammarino, S., Mastrostefano, V., & Silvani, A. (2001). Measuring the regional dimension of innovation: Lessons from the Italian Innovation Survey. Technovation, 21(11), 733-745.

Feldman, M. P., & Audretsch, D. B. (1999). Innovation in cities: Science-based diversity, specialization and localized competition. European Economic Review, 43(2), 409–429.

Feldman, M., Siegel, D. S., & Wright, M. (2019). New developments in innovation and entrepreneurial ecosystems. Industrial and Corporate Change, 28(4), 817–826.

Florida, R. (2002). The economic geography of talent. Annals of the Association of American Geographers, 92(4), 743–755.

Florida, R., Adler, P., & Mellander, C. (2018). The city as innovation machine. In Transitions in regional economic development (pp. 151–170). Routledge.

Frenken, K., & Boschma, R. A. (2007). A theoretical framework for evolutionary economic geography: Industrial dynamics and urban growth as a branching process. Journal of Economic Geography, 7(5), 635–649.

Garcia, R., & Calantone, R. (2002). A critical look at technological innovation typology and innovativeness terminology: A literature review. Journal of Product Innovation Management, 19(2), 110–132.

Gelman, A. (2007). Data analysis using regression and multilevel/hierarchical models. Cambridge University Press.

Glaeser, E. (2011). Cities, productivity, and quality of life. Science, 333(6042), 592–594.

Grilli, L., & Rampichini, C. (2015). Specification of random effects in multilevel models: A review. Quality & Quantity, 49, 967–976.

IAB/ZEW Start-up Panel. (2021). IAB and ZEW, Nürnberg and Mannheim, Germany. Retrieved October 20, 2022, from https://www.gruendungspanel.de/en/zew-start-up-panel/home.

Johansson, B., & Lööf, H. (2008). Innovation activities explained by firm attributes and location. Econ. Innov. New Techn., 17(6), 533–552.

Lentz, R., & Mortensen, D. T. (2008). An empirical model of growth through product innovation. Econometrica, 76(6), 1317–1373.

Li, Y., Vanhaverbeke, W., & Schoenmakers, W. (2008). Exploration and exploitation in innovation: Reframing the interpretation. Creativity and Innovation Management, 17(2), 107–126.

López-Bazo, E., & Motellón, E. (2018). Innovation, heterogeneous firms and the region: Evidence from Spain. Regional Studies, 52(5), 673–687.

Mason, C., & Brown, R. (2014). Entrepreneurial ecosystems and growth oriented entrepreneurship. Final report to OECD, Paris, 30(1), 77-102.

Meili, R., & Shearmur, R. (2019). Diverse diversities—Open innovation in small towns and rural areas. Growth and Change, 50(2), 492–514.

Nathan, M., & Lee, N. (2013). Cultural diversity, innovation, and entrepreneurship: Firm-level evidence from London. Economic Geography, 89(4), 367–394.

Naz, A., Niebuhr, A., & Peters, J. C. (2015). What's behind the disparities in firm innovation rates across regions? Evidence on composition and context effects. The Annals of Regional Science, 55, 131–156.

Niebuhr, A., Peters, J. C., & Schmidke, A. (2020). Spatial sorting of innovative firms and heterogeneous effects of agglomeration on innovation in Germany. The Journal of Technology Transfer, 45(5), 1343–1375.

North, D. (1990). Institutions and their consequences for economic performance. The limits of rationality, 383-401.

Protogerou, A., Kontolaimou, A., & Caloghirou, Y. (2017). Innovation in the European creative industries: A firm-level empirical approach. Industry and Innovation, 24(6), 587–612.

Rodríguez-Pose, A., & Crescenzi, R. (2008). Research and development, spillovers, innovation systems, and the genesis of regional growth in Europe. Regional Studies, 42(1), 51–67.

Schumpeter, J.A. (1934) The Theory of Economic Development, Cambridge, ma: Harvard University Press.

Spigel, B., & Stam, E. (2018). Entrepreneurial ecosystems. In SAGE Handbook of Entrepreneurship and Small Business (p. 21). Sage.

Stam, E., & Spigel, B. (2016). Entrepreneurial ecosystems (Vol. 16, No. 13, pp. 1-15). USE Discussion paper series.

Stam, E., & Van de Ven, A. (2021). Entrepreneurial ecosystem elements. Small Business Economics, 56(2), 809–832.

Stam, E., & Welter, F. (2020). Geographical contexts of entrepreneurship: Spaces, places and entrepreneurial agency. In The psychology of entrepreneurship (pp. 263–281). Routledge.

Sternberg, R. (2022). Entrepreneurship and geography—some thoughts about a complex relationship. The Annals of Regional Science, 69(3), 559–584.

Sternberg, R., & Arndt, O. (2001). The firm or the region: What determines the innovation behavior of European firms? *Economic Geography*, *77*(4), 364-382.

Tavassoli, S., Obschonka, M., & Audretsch, D. B. (2021). Entrepreneurship in cities. Research Policy, 50(7), 104255.

Tödtling, F., & Trippl, M. (2011). 33 Regional innovation systems. In Handbook of regional innovation and growth (pp. 455). Edward Elgar Publishing.

Vega-Jurado, J., Gutiérrez-Gracia, A., Fernández-de-Lucio, I., & Manjarrés-Henríquez, L. (2008). The effect of external and internal factors on firms' product innovation. Research Policy, 37(4), 616–632.

Wurth, B., Stam, E., & Spigel, B. (2022). Toward an entrepreneurial ecosystem research program. Entrepreneurship Theory and Practice, 46(3), 729–778.

4 Empirical Paper

Meijering, B. (2025). Can entrepreneurial ecosystems accommodate green start-ups? A regional systemic approach in Germany.

Manuscript submitted to *Small Business Economics*.

Abstract

Thus far, the relationship between entrepreneurial ecosystems (EEs) and green start-ups remains largely unexplored, mainly because EEs evolve around high-growth entrepreneurship. However, investigating this relationship is essential to understand why green start-ups may struggle to gain traction within conventional EEs and where ecosystem-level transformation is most needed to support ecological sustainability goals. This line of inquiry is also critical for advancing the conceptual development of the emerging sub-stream on sustainable entrepreneurial ecosystems (SEEs), which seeks to align ecosystem thinking with both ecological and social sustainability. The purpose of this study is to investigate which key contextual (f)actors and their interdependencies in traditional EEs are conducive to green start-up activity at the regional (NUTS-3) level in Germany. In doing so, firm-level data from the IAB/ZEW Start-up Panel (2021) were used. With the use of a multilevel model, differences in green start-up activity across urban, intermediate, and rural regions were accounted for. The findings show that while some traditional EE components are not supportive of green trajectories, others have the potential to enable green start-up activity when strategically leveraged, particularly by considering their systemic interdependencies.

Keywords: entrepreneurial ecosystems (EEs), sustainable entrepreneurship, green start-ups, regions, Germany.

4.1 Introduction

While entrepreneurial ecosystems (EEs) have been widely praised for driving high-growth entrepreneurship (Stam & Van de Ven, 2021), their role in supporting green start-ups remains largely unexplored. EEs are defined as a set of interdependent contextual (f)actors – e.g., knowledge, culture, physical infrastructure, and formal institutions – that support high-growth entrepreneurship within a given territory (Spigel, 2017; Spigel & Stam, 2018). Although effective in promoting economic growth in cities and regions (Stam, 2015), EEs have largely prioritized economic performance over environmental and social outcomes, often overlooking sustainability considerations (Volkmann et al., 2021). This is problematic given that many businesses are major contributors to environmental and social problems (Schaltegger & Wagner, 2011). Green start-ups, defined as firms younger than eight years that place ecological sustainability at the core of their business model, aim to balance economic success with environmental impact (Bergset & Fichter, 2015; Schaltegger & Wagner, 2011). However, the relationship between EEs and green start-ups has received limited scholarly attention thus far.

One important reason this relationship remains unexplored is the prevailing assumption in the literature that traditional EEs are inherently not well-suited to support sustainable entrepreneurship, both in terms of environmental and social outcomes (see e.g., Cohen, 2006). This perspective has led to the emergence of a distinct research stream on sustainable entrepreneurial ecosystems (SEEs), which are specifically designed to support sustainable entrepreneurship (Theodoraki et al., 2022). While SEEs offer a valuable novel framework and empirical SEE research is growing (see e.g., Bischoff, 2021; DiVito & Ingen-Housz, 2021; O'Shea et al., 2021; Pankov et al., 2021; Wagner et al., 2021), the notion that existing EEs cannot accommodate sustainable entrepreneurship is often taken for granted and lacks empirical grounding (Volkmann et al., 2021). However, uncovering this relationship is essential for understanding why sustainable forms of entrepreneurship may struggle to gain traction within traditional EEs and where ecosystem-level transformation is most needed to support them. Clarifying if and how traditional EEs can support sustainable entrepreneurship also helps distinguish the conceptual boundaries between EEs and SEEs and informs whether SEEs should be treated as an extension of existing EE frameworks or as a fundamentally distinct ecosystem model.

This study aims to investigate which key contextual (f)actors and their interdependencies in traditional EE are conducive to green start-up activity at the regional (NUTS-3) level in Germany. In this study, green start-ups are regarded as a subset of sustainable entrepreneurship that primarily prioritizes ecological sustainability, without necessarily encompassing the social dimension. Furthermore, studying these dynamics at the regional level is particularly important, as entrepreneurship is largely a regional phenomenon (Hess et al., 2025). However, as start-up activity varies between urban, intermediate, and rural regions (Fritsch & Storey, 2014), a multilevel linear regression model is used to account for these differences. The analysis draws on firm-level data from the IAB/ZEW Start-up Panel (2021).

This research serves as a bridge between the EE and SEE literature by contributing insights relevant to both. By examining the relationship between traditional EEs and green start-ups, it adds to the EE literature by extending the discussion beyond high-growth entrepreneurship to green start-ups (Volkmann et al., 2021). At the same time, it advances the conceptual development of SEEs by identifying where traditional EEs are capable of supporting green start-ups and where ecosystem-level transformation is needed to better accommodate these kinds of ventures.

4.2 Literature

4.2.1 Sustainable entrepreneurship

Sustainable entrepreneurship can be defined as a form of entrepreneurship that integrates ecological and social dimensions into its core objectives, aiming to create value across environmental, social, and economic domains following the triple bottom line (Schaltegger & Wagner, 2011). Rather than focusing solely on profit maximization, it operates in harmony with ecological and social systems and positions entrepreneurial activity as a vehicle for systemic change aligned with sustainability principles (Parrish, 2010; Shepherd & Patzelt, 2011).

While sustainable entrepreneurship intersects with the concepts of social and green (eco) entrepreneurship, it offers a broader, more integrated conceptualization. Social entrepreneurship is primarily concerned with addressing societal challenges, whereas green entrepreneurship focuses on mitigating environmental degradation through market-driven solutions (Muñoz & Cohen, 2018). Both concepts contribute to sustainability, but neither fully encapsulates the comprehensive vision of sustainable entrepreneurship, which incorporates both social and environmental dimensions into a cohesive framework for sustainable development (Shepherd & Patzelt, 2010). This distinction is crucial because sustainable entrepreneurship does not merely address isolated environmental or social issues but seeks to create synergistic solutions that account for the interdependencies between these domains.

This study focuses specifically on green entrepreneurship as a distinct yet complementary domain within the broader sustainable entrepreneurship literature. Green entrepreneurship is particularly salient in the context of ecological transition, as it directly addresses environmental challenges through business models (Schaper, 2016). While it does not fully encompass the social dimension, its contribution to a Sustainable Economy lies in catalyzing ecological change and driving the development of environmentally sustainable industries (Hall et al., 2010).

Defining green start-ups

Green entrepreneurship manifests across various stages of venture development, encompassing nascent entrepreneurs, start-ups, and established firms (Bergset & Fichter, 2015). However, green start-ups – defined as young firms that embed ecological sustainability at the core of their business models (Schaltegger & Wagner, 2011) – occupy a particularly critical role in advancing the transition toward a Green Economy. From a theoretical standpoint, green start-ups are situated at the intersection of innovation and ecological transformation, representing agents of change capable of disrupting incumbent industries through environmentally oriented value creation (Fichter & Clausen, 2016). Unlike established firms, green start-ups are often more agile and willing to pursue radical green innovations that challenge existing market paradigms (Weiß et al., 2013). In this sense, green start-ups align closely with Schumpeterian views of entrepreneurship as a force of creative destruction, with the added dimension of ecological impact (Baumol, 2010).

4.2.2 Entrepreneurial ecosystems (EEs)

Entrepreneurship does not happen in a vacuum, as entrepreneurs are embedded within the geographical context of their particular local, regional, national, or even global economy (Welter & Gartner, 2016). This idea is well reflected in the popular concept of EEs (Welter & Stam, 2020). EEs play an important role in the foundation and growth of ventures (Isenberg, 2010). An EE is defined as a set of interdependent actors and factors that support growth-oriented entrepreneurship in a given territory (Spigel & Stam, 2016). It consists of resources such as physical infrastructure, intermediaries, talent, knowledge, and finance, as well as institutional arrangements, including formal institutions, networks, and culture (Stam & Van de Ven, 2021). Stam (2015, p. 5) asserts that "the systemic conditions are the heart of the ecosystem." These systemic conditions encompass the interdependencies between various actors and factors within the ecosystem (Roundy et al., 2018). For example, physical infrastructure plays a crucial role in facilitating seamless collaboration and improving market access. In this way, EEs act as powerful catalysts for high-growth entrepreneurship through the resources, institutional environments, and their interdependencies (Wurth et al., 2022).

The lack of sustainability in EEs

However, the concept of EEs faces notable challenges, especially due to its limited focus on sustainability (Theodoraki et al., 2022). Traditionally, EEs have been designed to support high-growth entrepreneurship, prioritizing economic growth, job creation, and innovation in line with conventional growth models (Stam, 2015). This focus has, in turn, allowed entrepreneurs to deprioritize their responsibilities toward the environment and society, contributing to ecological degradation, social inequality, and the overuse of natural resources, further exacerbating sustainability challenges (Daly & Farley, 2011). Alternative economic paradigms, such as post-growth and degrowth theories, challenge the conventional growth models embedded in EEs. They argue that traditional economic growth can become counterproductive when it leads to overconsumption, environmental degradation, and rising inequality (Affolderbach & Schulz, 2024; Schulz & Bailey, 2014). Instead, these paradigms prioritize sustainable well-being over mere economic output, contending that increases in GDP or material wealth do not necessarily translate into improvements in social or environmental well-being (Schulz & Braun, 2021). From this perspective, the structural focus of EEs on high-growth entrepreneurship may inadvertently reinforce unsustainable entrepreneurial trajectories.

Recognizing the limitations of traditional EEs, scholars have begun to reframe these ecosystems through the lens of sustainability, giving rise to the novel concept of sustainable entrepreneurial ecosystems (SEEs). The theoretical distinction between EEs and SEEs lies in their foundational objectives: while EEs are typically designed to promote high-growth entrepreneurship, SEEs are structured to foster entrepreneurial activities that align with sustainability imperatives, transcending conventional growth models (Theodoraki et al., 2022). From a theoretical perspective, the formation of SEEs is not merely an adaptation of traditional EEs but involves a more profound transformation in institutional arrangements, resources, and actor interactions. The role of public policy, governance, and cultural norms becomes critical in facilitating this transformation, as these elements help reconfigure market incentives, regulatory frameworks, and social expectations to align with sustainable development goals (Bischoff, 2021; O'Shea et al., 2021; Takyi & Naidoo, 2020). Additionally, universities, through their knowledge creation and dissemination capabilities, emerge as pivotal institutions in SEEs, enabling the diffusion of eco-innovations and fostering a culture of sustainable entrepreneurship (Schaltegger & Wagner, 2011; Torres Valdés et al., 2019). In this regard, the theory of SEEs posits that sustainable entrepreneurship requires a unique set of interconnected (f)actors that go beyond the resources and institutional arrangements typically found in traditional EEs.

Despite growing theoretical interest in SEEs, there remains a lack of empirical research on how sustainable entrepreneurship is constrained by traditional EEs (Volkmann et al., 2021). While SEE theory emphasizes the need for distinct institutional arrangements, cultural norms, and resource flows tailored to sustainability goals, it is still unclear how these requirements diverge from the structures of traditional EEs. This gap in empirical knowledge makes it difficult to assess whether traditional ecosystems can be adapted to support sustainable entrepreneurship or whether entirely new configurations are, indeed, needed. At the same time, following transition theory and systems thinking, meaningful sustainability transitions require deep structural shifts in existing socio-economic systems (Voulvoulis et al., 2022) – entailing changes not only in entrepreneurial behaviour but also in the underlying structures of existing, traditional EEs. While the concept of SEEs offers a compelling vision, focusing solely on SEEs overlooks the fact that traditional EEs remain dominant and deeply embedded in current policy and economic practice. Therefore, traditional EEs should be viewed as critical leverage points for systemic change by revealing the barriers that hinder sustainable entrepreneurship and identifying where transformation is most needed.

4.3 Data and methods

4.3.1 Firm-level data

This study uses firm-level data from the IAB/ZEW Start-up Panel (2021) – previously known as the KfW/ZEW Start-up Panel – of the Centre for European Economic Research (ZEW). The panel covers annual surveys conducted in start-ups from 2008-2021, yet information on the environmental objectives of start-ups is only available in 2021 and 2018. This study uses data from 2021 (reference year: 2020) on 6776 start-ups to avoid a time lag with the regional data. In the panel, start-ups are defined as firms younger than eight years old run by at least one full-time entrepreneur; de-merger foundations and subsidiaries are not included in the panel. The data cover all industries, excluding agriculture, mining and quarrying, electricity, gas and water supply, health care, and the public sector. The annual surveys are conducted once a year with computer-aided telephone interviews (CATI) and cover information related to the entrepreneur(s) and the firm, including the headquarters office at the regional (NUTS-3) level.

Dependent variable

The panel uses a definition of green start-ups based on energy and overall CO_2 reduction within the company. In the annual survey, start-ups were asked if they slightly (2 = yes, low), significantly (1 = yes, significant), or not at all (0 = no) reduced their energy consumption and/or overall CO_2 within the company. This study captures start-ups that only significantly did so because environmental protection takes a more central role in their business models (Schaltegger & Wagner, 2011). The dependent variable measures the number of start-ups that significantly reduced energy consumption or the overall CO_2 balance in the company at the regional (NUTS-3) level.

Sample

The sample consists of 390 (NUTS-3) regions – from the 401 regions in the year 2020 – due to firm-level data availability. From the initial 6776 start-ups, 1007 start-ups significantly reduced energy consumption and/or the overall CO_2 balance in the company in 2020.

Firm-level controls

Two important firm-level controls were included because of their potential influence on the outcome. These firm-level controls were aggregated at the regional (NUTS-3) level. First, the in-house R&D in a region is found to be representative of the number of sustainable firms in the region (Hájek & Stejskal, 2018). Second, regions dominated by manufacturing industries are often characterized by high carbon footprints and a lack of sustainability in local firms (Delgado-Gomes et al., 2017). Capturing the in-house R&D and dominance of manufacturing industries in the region may thus predict green start-up activity, as one dimension of sustainability.

4.3.2 Region-level data

The aggregated firm-level data are linked to regional (NUTS-3) data. The region-level data are represented by the elements of the traditional, growth-oriented EE (Stam & Van de Ven, 2021). However, measuring a "traditional" EE presents challenges due to the diverse methodologies and metrics used by different scholars to assess its various elements. In this study, the ten elements are measured based on widely recognized metrics in the EE literature (see Table 4-1), frequently referring to Stam and other scholars who have contributed to the development of the concept. However, this does not imply that a traditional EE is strictly confined to these specific measurements. Notably, some variables had missing data in the reference year; hence, a time lag was applied. When NUTS-3 data were unavailable, NUTS-2 values were imputed at the NUTS-3 level.

TABLE 4-1. Measurement of the elements of the traditional EE.

Indicators	**Measurement in time <>**	**Source in the literature <>**	**NUTS-level**	**Data source and availability <>**
Formal institutions	Quality of Government Index based on the level of corruption, unaccountability, and impartiality <2021>	Leenderste et al. (2022); Stam & Van de Ven (2021)	NUTS-2	European Quality of Institutions Index and DG Region's own computations in the RCI (2022)
Entrepreneurial culture	Percentage of self-employed per 100 members of the workforce <2020>	Fritsch & Wyrwich (2018); Stam & Spigel (2016)	NUTS-3	Ongoing spatial monitoring of the BBSR (2000-2023);
Networks	Percentage of SMEs with innovation cooperation activities <2021>	Leendertse et al. (2022)	NUTS-2	Regional Innovation Scoreboard (DG GROW) in the RCI (2022)
Market demand	GDP per capita <2020>	Stam (2017)	NUTS-3	Ongoing spatial monitoring of the BBSR (2000-2023).
Intermediaries	Indirect federal grants for R&D projects in 1000 Euros per member of the working-age population <2017>	OECD (2018)	NUTS-3	BMBF (1991-2017)
Talent	Percentage of students at universities and universities of applied sciences per 1,000 inhabitants <2020>	Stam & Van de Ven (2021)	NUTS-3	Ongoing spatial monitoring of the BBSR (2006-2021);
Knowledge	Intramural R&D expenditure as % of GDP <2019>	Leendertse et al. (2022); Stam & Van de Ven (2021)	NUTS-2	Eurostat, Regional Science and Technology Statistics in the RCI (2022)
Leadership	EU research framework program H2020 in 1000 Euros per member of the working-age population <2017>	Leendertse et al. (2022)	NUTS-3	EU-Kommission, Vertragsdatenbank zur Beteiligung am EU-Forschungsrahmenprogramm (2014-2017)

Finance	Percentage of start-ups that received loans, venture capital, or funds at least once <2018-2020[10]>	Stam & Spigel (2018)	NUTS-3	IAB/ZEW Start-up Panel (2021)

Institutional arrangements

At the level of institutional arrangements, formal institutions reflect the rules of the game in society (North, 1990) and are measured by the level of corruption, unaccountability and partiality of government services in the region based on the Quality of Government Index (Leendertse et al., 2022; Stam & Van de Ven, 2021). Entrepreneurial culture reflects the degree to which entrepreneurship is valued in society, which is measured by the number of self-employed per 100 members of the workforce (Fritsch & Wyrwich, 2018; Stam & Spigel, 2016). Lastly, networks indicate the connectedness of businesses for new value creation and are measured by the share of SMEs in percentage with innovation cooperation activities (Leendertse et al., 2022).

Resource endowments

At the level of resource endowments, physical infrastructure can facilitate labour mobility and the exchange of knowledge and ideas (Audretsch & Belitski, 2017). This can be measured by railway or public transportation accessibility (Stam & Van de Ven, 2021). Potential accessibility can be measured by two functions: the activity function, representing the activities to be reached, and the impedance function, representing the effort, time, distance, or cost required to reach them (Spiekermann et al., 2002, as cited in Stam & Spigel, 2016). This study uses the number of public transportation (train, tram, bus, and metro) departures per capita as a measure of the activity function. It indicates how well-served an area is by public transit – regions with frequent departures per person generally provide better accessibility. Furthermore, the potential market demand provides an estimate of the GDP and population available within an area (Stam, 2017) and is measured by GDP per capita. Talent can be measured in many ways, entrepreneurship-specific (Stam & Spigel, 2018) and more generic (Unger et al., 2011). Similar to Stam and Van de Ven (2021), a generic measure of human capital is used, measured by the number of students at universities and universities of applied sciences per 1,000 inhabitants. Knowledge reflects the investments in (scientific and technological) knowledge

[10] These are all the years available in the panel data from 2021.

creation, which is measured by intramural R&D expenditure as a percentage of GDP (Leendertse et al., 2022; Stam & Van de Ven, 2021). Finance represents the presence of financial means for entrepreneurship through the ease of access to venture capital, loans, or funds (Stam & Spigel, 2018). It is measured by the percentage of start-ups that received external financial support in loans, venture capital, or funds. Leadership provides guidance for and direction of collective action (Feld, 2020; Stam & Van de Ven, 2021) and is often measured through Horizon 2020 (H2020) projects (Leendertse et al., 2022). In this study, leadership is measured by the amount of EU research framework program H2020 (in 1,000 Euros) per working-age population member. Intermediaries can substantially lower the barriers and increase the speed of new value creation (Stam & Van de Ven, 2021) and are often measured by the number of incubators/accelerators per capita (Leenderste et al., 2022). Due to the unavailability of public regional (NUTS-3) data on incubators or accelerators, intermediaries are measured using the amount of indirect federal grants (in 1,000 Euros) allocated to projects supporting SMEs in their R&D activities per working-age population member. While this does not exclusively measure incubators or accelerators, these grants are intended to support the development and enhancement of technology and innovation services, including incubators and accelerators (OECD, 2018). Using the working-age population instead of per capita to measure leadership and intermediaries is preferable because it better reflects the economic and research-active segment of the population.

4.3.3 Classification of region types

Entrepreneurship is deeply embedded in its context, where different types of regions can shape distinct entrepreneurial processes, challenges, and outcomes (Shepherd, 2011). For example, urban regions are often seen as “munificent” environments for entrepreneurship in that they offer abundant resources, including advanced infrastructure, larger markets, and stronger institutional support, while rural regions face challenges like limited market access, weaker infrastructure, and fewer support services (Bosma & Sternberg, 2017).

To control for these regional differences, a classification of NUTS-3 regions in urban, intermediate, and rural regions is used based on the concentration of population, jobs, and the geographical proximity to these areas (BBSR, 2021). The geographical proximity is measured using the BBSR accessibility model. The centrality index of the accessibility model cumulates the daily population (inhabitants plus inbound commuters minus outbound commuters) that can reach settlement centres within two hours of travel time by motorized private transport. The data consist of 211 urban, 84 intermediate, and 95 rural regions.

4.3.4 Model

A multilevel linear regression model is chosen because the data is structured hierarchically, meaning that the observations of green start-ups are nested within larger units (Leeuw & Meijer, 2008). With a random intercept model, the baseline level of the outcome is allowed to vary across region types, while slopes remain fixed (Snijders & Bosker, 2011).

Within the model, two-way interaction terms are included to model the interdependencies between the elements of the ecosystem. Preferably, interaction terms are identified through theory (Franzese & Kam, 2009). However, with the lack of a theoretical foundation on how traditional EEs and green start-ups relate (Volkmann et al., 2021), interaction terms are identified through underlying data structures. As stated by Leendertse et al. (2022), potential interaction effects between the elements of the ecosystem can be detected through Principal Component Analysis (PCA). PCA is a statistical method for reducing dimensionality by transforming a set of potentially correlated variables into a smaller set of uncorrelated principal components (PCs) (Greenacre et al., 2022). The continuous independent variables included in the PCA were all standardized according to z-scores. A closer examination of the loadings in Figure 4-1 helps to identify potential interaction effects through the clustered behaviour of certain variables, meaning that the effect of one variable on the outcome might be modified or influenced by the presence of another variable. Variables with large positive or negative loadings on PC1 (explaining the largest proportion of variance) exceeding ± 0.5 were interpreted as having potential interaction effects in Table 4-2 (Jolliffe, 2002). Using PC1 only prevents overcomplicating the analysis by focusing on the most meaningful relationships rather than weaker patterns found in other PCs. This method aligns with the parsimony principle, ensuring that conclusions are drawn from the strongest signals in the data.

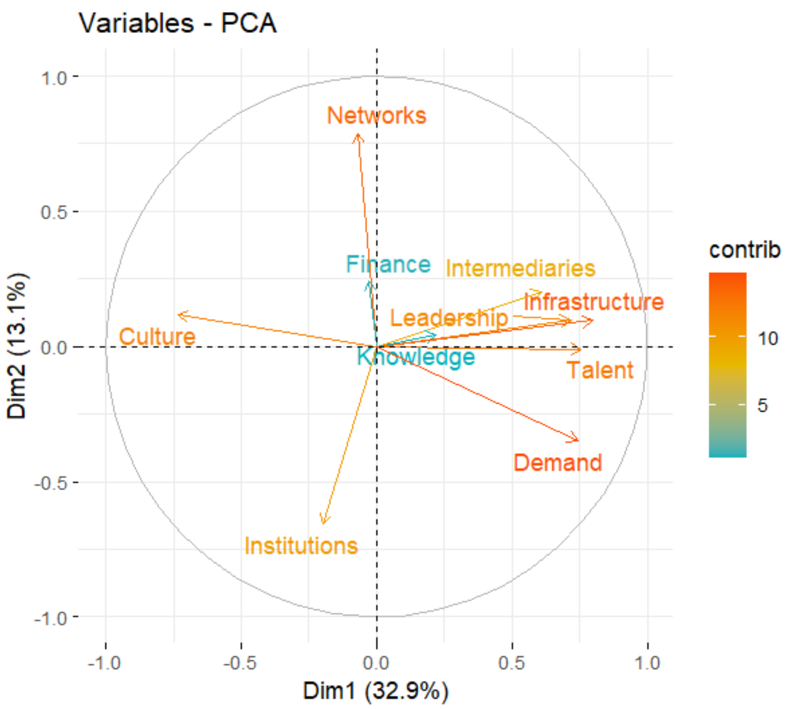

FIGURE 4-1. Principal Component Analysis (PCA) on EE elements.

Principal Component Analysis (PC1), loadings exceeding ±0.5	
Culture	–0.734
Intermediaries	0.610
Leadership	0.718
Talent	0.757
Infrastructure	0.801
Demand	0.745
Proportion of Variance (%)	32.885
Standard Deviation	1.810

TABLE 4-2. Principal Component 1 on the EE elements with loadings exceeding ±0.5.

However, if PCA is used alone without significance testing, there is a risk of including irrelevant or spurious interaction terms that do not contribute to the predictive power of the model (Jolliffe & Cadima, 2016). A Wald Test is a useful method for assessing which clusters of variables identified through PCA in Table 4-2 have a statistically significant joint effect on the outcome (Sommer & Huggins, 1996). Table 4-3 shows the significant interaction effects of the Wald Test to include in the multilevel linear regression model.

Wald Test	**Statistic**	***P*-value**
Culture X Transport	9.065	0.003 **
Culture X Demand	5.955	0.015 *
Culture X Intermediaries	4.612	0.032 *
Culture X Leadership	4.120	0.042 *
Transport X Demand	5.710	0.017 *

Table 4-3. Significance testing of two-way interaction effects through Wald Test. *** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$.

The model specification is as follows:

$$Y_{ij} = \beta_0 + \sum_{k=1}^{K} \beta_k X_{ik} + Q(X_{i1} \cdot Z_j) + u_j + \epsilon_{ij}, \text{ where:}$$

- Y_{ij} is the number of green start-ups for the *i*-region in the *j*-region type;
- β_0 is the fixed intercept;
- $\sum_{k=1}^{K} \beta_k X_{ik}$ is the summation of *K* predictor variables (X_{ik}) for the *i*-region, each with its fixed effect coefficient β_k;
- *Q* is the coefficient of the two-way interaction term, capturing how the effect of X_{i1} on Y_{ij} changes depending on Z_j;
- u_j is the random intercept for the *j*-region type, capturing deviations of the *j*-region type's intercept from the overall intercept β_0;
- ϵ_{ij} is the residual error term for the *i*-region within the *j*-region type, capturing deviations of observed Y_{ij} from the predicted value after accounting for fixed and random effects.

4.3.5 Descriptive statistics

Table 4-4 represents the descriptive statistics. Before the analysis, all continuous independent variables were standardized according to z-scores to mitigate the influence of outliers and to ensure comparability across variables. The descriptive statistics of the standardized variables are represented in Table 4-6 in the Appendix. To control for multicollinearity, the variance inflation factor (VIF) was calculated (see Table 4-7 in the Appendix). There is no concerning level of multicollinearity (mean = 1.550).

TABLE 4-4. Descriptive statistics (*n* = 390).

Descriptive statistics	Mean	St. Dev.	Min	Max
Green start-ups	2.582	3.505	0.000	39.000
Region type (SAM2020)	1.703	0.835	1.000	3.000
In-house R&D (mean)	15406.750	25099.650	0.000	200000.000
Manufacturing industries (mode)	0.697	0.460	0.000	1.000
Culture	9.499	2.042	2.342	14.679
Intermediaries	49.344	166.852	0.000	2717.650
Leadership	16.324	47.196	0.000	620.477
Talent	17.096	44.023	0.000	365.570
Networks	93.021	45.058	44.816	192.749
Knowledge	2.887	1.660	0.857	7.773
Finance	15.025	10.977	0.000	60.000
Infrastructure	0.152	0.076	0.007	0.423
Institutions	0.910	0.196	0.314	1.235
Demand	37.851	16.075	16.661	167.117

4.4 Results

Table 4-5 shows the results of the linear multilevel regression model. The intraclass correlation (ICC) reveals that 6.86% of the total variance is explained by differences between region types, while the remaining 93.14% is due to individual differences within groups. Because of the nature of entrepreneurship, it is not surprising that the variation between individuals within a type of region strongly outweighs the variation across different types of regions (Acs & Audretsch, 2010). However, the variation across region types is significant (see Table 4-5), which confirms the choice of a multilevel model. The fixed effects regression results are shown in Table 4-5. Table 4-5 shows that the firm-level controls are not significant. More specifically, internal R&D and manufacturing industries in the region do not significantly influence green start-up activity. However, within traditional EEs, certain elements and their interdependencies are significantly associated with green start-up activity. Nevertheless, this pattern is not consistent across the entire ecosystem, revealing gaps and limitations in its overall capacity to support green start-ups.

TABLE 4-5. The multilevel linear regression model with fixed effects and a random intercept.

Fixed effects:					
	Estimate	**Std. Error**	**t value**	**Pr(>|t|)**	
(Intercept)	2.742	0.574	4.780	0.012	*
In-house R&D	0.163	0.162	1.005	0.316	
Manufacturing industries	0.554	0.353	1.568	0.118	
Institutions	-0.853	0.212	-4.029	0.000	***
Culture	1.201	0.251	4.786	0.000	***
Networks	-0.347	0.175	-1.981	0.048	*
Infrastructure	0.467	0.252	1.853	0.065	
Demand	1.475	0.353	4.173	0.000	***
Intermediaries	1.585	0.553	2.869	0.004	**
Knowledge	-0.137	0.167	-0.820	0.413	
Talent	0.279	0.233	1.201	0.231	
Leadership	-0.402	0.321	-1.254	0.211	
Finance	0.081	0.159	0.510	0.610	
Culture X Infrastructure	0.888	0.252	3.531	0.000	***
Culture X Demand	0.613	0.168	3.646	0.000	***
Infrastructure X Demand	0.739	0.242	3.055	0.002	**
Culture X Intermediaries	1.084	0.385	2.813	0.005	**
Culture X Leadership	0.008	0.269	0.029	0.977	
Random variance	0.663			0.000	***
Likelihood Ratio Test (Chisq)	108.39			6.26e-15	***
AIC	2025.2				

There is a significant and negative relationship between the quality of formal institutions and green start-ups in regions. This does not imply that well-regulated regions with a high Quality of Government Index are inherently unfavourable to sustainable entrepreneurship.

However, existing regulatory frameworks are often primarily designed for traditional industries, causing sustainable entrepreneurs to face more institutional barriers in terms of a lack of financial, administrative, and informational support (Hoogendoorn et al., 2019). Hence, current regulatory frameworks are not optimally structured to facilitate green start-up activity.

In a similar vein, there is a significant and negative relationship between networks, measured through SMEs with innovative cooperation activities, and green start-up activities. This finding may seem counterintuitive at first because networks, in general, are conducive to entrepreneurship through opportunity recognition and facilitating the mobilization of resources (Stuart & Sorenson, 2007). However, innovation collaborations among SMEs are often deeply embedded in regional industrial structures, which may rather reinforce conventional business models than sustainability-oriented ones (Asheim & Coenen, 2005). This dynamic may partly explain the lower prevalence of green start-ups in regions with dense SME innovation networks, although this relationship is likely more complex and context-specific, potentially influenced by factors such as regional industry specialization.

In contrast, there is a significant and positive relationship between entrepreneurial culture, measured by the level of self-employment, and green start-up activity in regions. Bischoff (2021) has already highlighted the importance of a supportive entrepreneurial culture for sustainable entrepreneurship. A supportive entrepreneurial culture nurtures innovation, risk-taking, and proactive problem-solving, creating an environment where green start-ups can be more easily established and thrive (Fritsch & Wyriwch, 2018). This finding suggests that certain components of traditional EEs can, under the right conditions, actively support green start-ups. Furthermore, Table 4-5 shows that the significant positive effect of entrepreneurial culture is amplified by the availability of physical infrastructure. The predicted probabilities at 95% CIs of this significant interaction effect are shown in Figure 4-2. In this sense, a well-developed regional physical infrastructure significantly increases the positive effect of entrepreneurial culture on green start-up activity in regions. After all, the positive effect of role models, among others that constitute the entrepreneurial culture, on green start-ups in the region will be greater if they are accessible, for example, by public transportation (Bosma et al., 2012).

Interestingly, physical infrastructure in isolation is not significant. This underscores the importance of considering EEs systemically (Wurth et al., 2022). In Table 4-5, a significant interaction effect is found, where the significant positive effect of physical infrastructure on green start-ups is amplified by the regional demand. The predicted probabilities at 95% CIs of this significant interaction effect are shown in Figure 4-3. When physical infrastructure is well-developed, it enhances the ability of start-ups to respond to consumer demand (Audretsch et al., 2015). Conversely, without consumers who prioritize sustainability, green start-ups lack the financial foundation to grow, rendering even the best infrastructure ineffective.

Additionally, intermediaries have a significant and positive effect on green start-ups in regions (see Table 4-5). They help start-ups develop a purpose, a cultural mindset, and business models in which (ecological) sustainability has become more often an essential requirement for companies (Bonfanti et al., 2024). Also, the positive effect of entrepreneurial culture on green start-ups is significantly amplified by regional intermediary services. The predicted probabilities at 95% CIs of this significant interaction effect are shown in Figure 4-4. Tiba et al. (2020) have already discussed how the interactions between culture and actors, such as mentors found in intermediary services, reinforce sustainability-based outcomes within an ecosystem. Intermediary services can help translate the regional culture that values entrepreneurship into concrete (sustainable) business practices.

Aside from intermediary services, the regional market demand also amplifies the significant positive effect of entrepreneurial culture on green start-ups in regions. The predicted probabilities at 95% CIs of this significant interaction effect are shown in Figure 4-5. Regional market demand serves as a key economic driver that complements the regional culture and also has a direct, significant, and positive effect on green start-ups in regions (see Table 4-5). The presence of a strong customer base ensures that start-ups can sustain operations, attract investment, and scale effectively (Spigel & Stam, 2016). When market demand aligns with a region's entrepreneurial culture, it creates a reinforcing cycle on green start-up activity: the regional culture promotes green entrepreneurship, while demand ensures business viability.

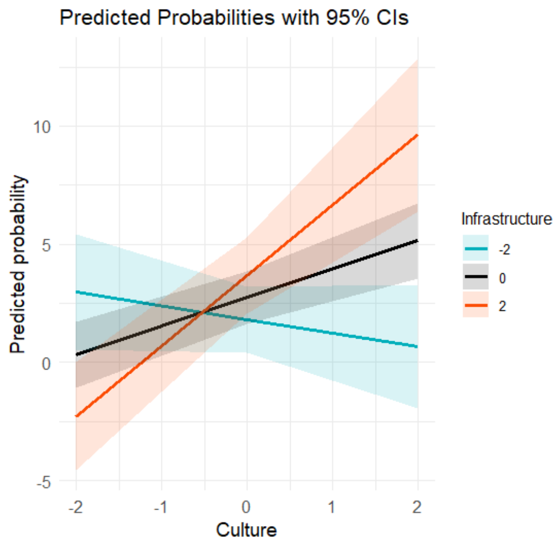

FIGURE 4-2. Predicted probabilities (1).

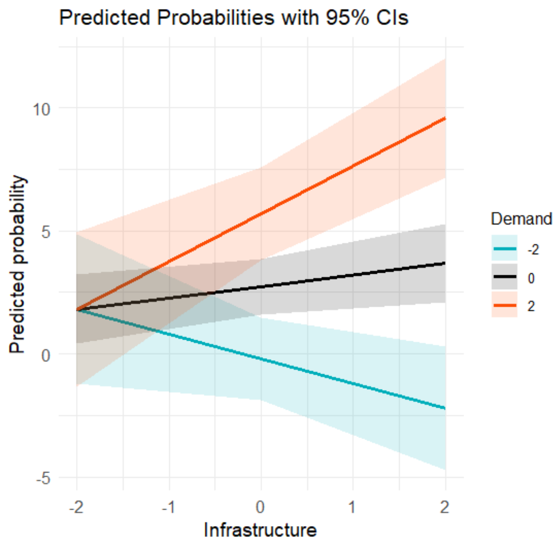

FIGURE 4-3. Predicted probabilities (2).

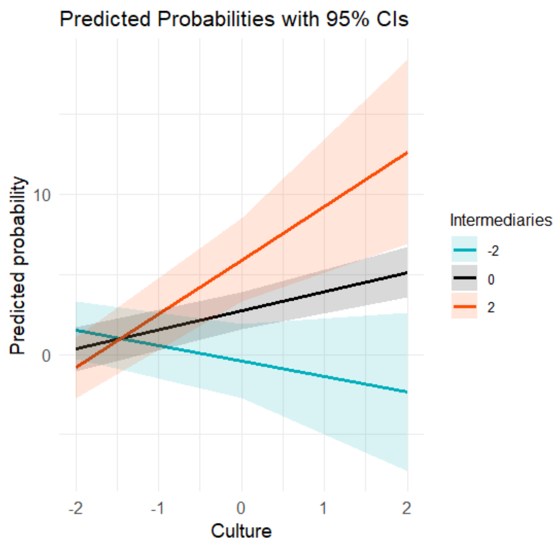

FIGURE 4-4. Predicted probabilities (3).

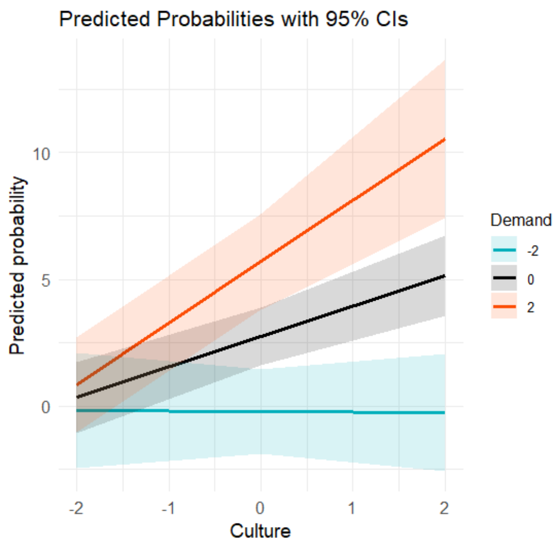

FIGURE 4-5. Predicted probabilities (4).

4.5 Discussion and Conclusion

This study examined which key contextual (f)actors and their interdependencies in traditional EE are conducive to green start-up activity at the regional (NUTS-3) level in Germany. Since start-up activity varies between urban, intermediate, and rural regions, a multilevel linear regression model was used to account for these differences (Fritsch & Storey, 2014). The contribution to the EE literature lies in understanding how traditional EEs and green start-ups, as a subtype of sustainable entrepreneurship, relate (Volkmann et al., 2021).

The findings indicate that formal institutions (measured by the Quality of Government Index) and networks (SMEs with innovation cooperation activities) are negatively associated with green start-ups in regions. This can be understood as a form of lock-in, where formal rules and network collaborations tend to be structured around conventional business models that prioritize economic growth over environmental goals. Innovation networks, for example, often evolve within existing regional industrial structures (Asheim & Coenen, 2005) that tend to reinforce business trajectories and norms in line with conventional growth models – what some scholars refer to as path dependency (Hassink, 2005). In such contexts, sustainable ventures may find it difficult to access appropriate funding, legitimacy, or collaborative opportunities, as their goals and practices diverge from the dominant logic. Therefore, these negative associations may not reflect a general inefficiency of formal institutions or networks, but rather a misalignment between the prevailing structures of traditional EEs and the unique needs of green start-ups. This insight underscores the importance of reconfiguring ecosystem components to break free from systemic lock-ins that inhibit transformative entrepreneurship.

However, in contrast to these limitations, this study aligns with Raposo et al. (2022) in showing that not all elements of traditional EEs are incompatible with ecological sustainability goals. In particular, the regional entrepreneurial culture and the presence of intermediary services are found to significantly and positively influence green start-ups. In regions where entrepreneurship is culturally celebrated, green start-ups may find greater legitimacy and encouragement to experiment with green solutions. Likewise, intermediary services can play a crucial role in reducing uncertainty, offering access to finance, networks, and knowledge that are particularly valuable for green start-ups, which often face higher market and regulatory risks (Hoogendoorn et al., 2019). Furthermore, the regional market demand also appears to support green start-up activity. However, from a post-growth or degrowth perspective, this raises critical questions. While GDP per capita may create enabling conditions for green start-ups, it also reflects an economic model that prioritizes continuous growth, which is fundamentally at odds with the degrowth imperative of reducing material throughput and environmental impact (Kallis et al., 2018). Therefore, it remains unclear whether such growth-linked prosperity truly facilitates sustainability transitions or merely enables marginal green business models within existing unsustainable paradigms. This underscores the need for a more nuanced understanding of how GDP per capita interacts with both the opportunities and limitations of green entrepreneurship. Thus, while certain traditional EE components may reinforce unsustainable paths, others hold the potential to enable sustainable entrepreneurship when strategically leveraged or reoriented. This recognition opens up theoretical avenues for exploring how SEEs and traditional EEs might overlap, interact, or even converge.

Importantly, the findings highlight the need to understand EEs as dynamic systems, where interdependencies between contextual (f)actors shape outcomes in complex ways (Wurth et al., 2022). Rather than viewing elements such as culture, physical infrastructure, and market demand in isolation, this study underscores how their combined effects are critical to fostering green start-ups. In particular, the interplay between entrepreneurial culture and physical infrastructure, market demand, and intermediary services appears pivotal in enabling ecosystems to support green start-ups. This systemic perspective reinforces the need for integrated, context-sensitive strategies when aiming to transform traditional EEs toward more ecologically sustainable systems.

The findings have several implications for policymakers. Policymakers should critically reassess formal institutions and SME innovation networks to better accommodate the unique needs of green start-ups, rather than defaulting to models tailored to conventional businesses. By doing so, EEs can become more inclusive, balancing economic growth with environmental impact (Chaudhary et al., 2023). Furthermore, regional policies should focus on strengthening entrepreneurial culture and intermediary services because of their positive effect on green start-up activity. However, investments should be made strategically, ensuring that they complement and enhance other critical EE components in their support towards green start-ups. In other words, a holistic policy approach is needed – one that identifies key components, strengthens their synergies and acknowledges that not all components of traditional EEs equally support green start-ups.

4.5.1 Limitations and future research

This study has various limitations and suggestions for future research. First, a limitation lies in the narrow operationalization of green start-ups as firms that reduce internal energy consumption or CO_2 emissions due to firm-level data availability. Future studies should adopt a more robust and mission-oriented definition of green start-ups. For example, one that considers whether environmental objectives are embedded in the firm's core mission to help distinguish genuinely green ventures from conventional firms that implement eco-efficient practices, for example, for regulatory reasons. Second, future research could use more fine-grained regional data to analyze how traditional EEs are conducive to green start-up activity because several NUTS-2 values were imputed to the NUTS-3 level due to a lack of NUTS-3 data. Third, future studies could explore how traditional EEs interact with other kinds (or subtypes) of sustainable entrepreneurship, for example, impact start-ups. Are there any key differences with green start-ups? After all, uncovering enablers and barriers of sustainable entrepreneurship in traditional EEs is essential for understanding where ecosystem-level transformation is most needed. This may also further help conceptually develop SEEs by questioning in what ways SEEs diverge from EEs in their support towards sustainable entrepreneurship. Fourth, although this study has only tackled the question of how traditional EEs enable green start-up activity, future research could explore how EEs and SEEs interact and reinforce each other's impact. Can EEs and SEEs co-exist, or are these mutually exclusive concepts?

4.6 Appendix

TABLE 4-6. Descriptive statistics with the standardized continuous independent variables (n = 390).

Descriptive statistics	Mean	St. Dev.	Min	Max
Green start-ups	2.582	3.505	0	39
Region type (SAM2020)	1.703	0.835	1	3
In-house R&D (mean)	0	1	-0.614	7.354
Manufacturing industries (mode)	0.697	0.460	0	1
Culture	0	1	-3.505	2.536
Intermediaries	0	1	-0.296	15.992
Leadership	0	1	-0.346	12.801
Talent	0	1	-0.388	7.916
Networks	0	1	-1.07	2.213
Knowledge	0	1	-1.223	2.943
Finance	0	1	-1.369	4.097
Infrastructure	0	1	-1.922	3.59
Institutions	0	0.808	-2.269	1.452
Demand	0	1	-1.318	8.041

TABLE 4-7. Variance inflation factor (VIF).

	VIF
In-house R&D	1.110
Manufacturing industries	1.097
Institutions	1.205
Culture	2.099
Networks	1.161
Infrastructure	2.251
Demand	2.168
Intermediaries	1.441
Knowledge	1.168
Talent	1.982
Leadership	1.869
Finance	1.047

4.7 References

Acs, Z. J., & Audretsch, D. B. (2010). Handbook of entrepreneurship research: An interdisciplinary survey and introduction. Springer.

Affolderbach, J., & Schulz, C. (2024). Wirtschaftsgeographien der Nachhaltigkeit. UTB.

Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. Research Policy, 34(8), 1173–1190.

Audretsch, D. B., & Belitski, M. (2017). Entrepreneurial ecosystems in cities: Establishing the framework conditions. The Journal of Technology Transfer, 42, 1030–1051.

Audretsch, D. B., Falck, O., Feldman, M. P., & Heblich, S. (2012). Local entrepreneurship in context. Regional Studies, 46(3), 379–389.

Audretsch, D. B., Heger, D., & Veith, T. (2015). Infrastructure and entrepreneurship. Small Business Economics, 44, 219–230.

Baumol, W. J. (2010). The microtheory of innovative entrepreneurship. In The Microtheory of Innovative Entrepreneurship. Princeton University Press.

Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR). (2021). Indikatoren und Karten zur Raum- und Stadtentwicklung: INKAR. Retrieved November 17, 2021, from https://www.inkar.de/.

Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR). (2021). Raumgliederungen des BBSR. Retrieved September 9, 2021, from https://www.bbsr.bund.de/BBSR/DE/forschung/raumbeobachtung/Raumabgrenzungen/raumabgrenzungen-uebersicht.html.

Bergset, L., & Fichter, K. (2015). Green start-ups—A new typology for sustainable entrepreneurship and innovation research. Journal of Innovation Management, 3(3), 118–144.

Bischoff, K. (2021). A study on the perceived strength of sustainable entrepreneurial ecosystems on the dimensions of stakeholder theory and culture. Small Business Economics, 56, 1121–1140.

Bosma, N., & Sternberg, R. (2017). Entrepreneurship as an urban event? Empirical evidence from European cities. In Entrepreneurship in a Regional Context (pp. 78–95). Routledge.

Bosma, N., Hessels, J., Schutjens, V., Van Praag, M., & Verheul, I. (2012). Entrepreneurship and role models. Journal of Economic Psychology, 33(2), 410–424.

Chaudhary, S., Kaur, P., Alofaysan, H., Halberstadt, J., & Dhir, A. (2023). Connecting the dots? Entrepreneurial ecosystems and sustainable entrepreneurship as pathways to sustainability. Business Strategy and the Environment, 32(8), 5935–5951.

Cohen, B. (2006). Sustainable valley entrepreneurial ecosystems. Business Strategy and the Environment, 15(1), 1–14.

Daly, H. E., & Farley, J. (2011). Ecological economics: Principles and applications. Island Press.

Delgado-Gomes, V., Oliveira-Lima, J. A., & Martins, J. F. (2017). Energy consumption awareness in manufacturing and production systems. International Journal of Computer Integrated Manufacturing, 30(1), 84–95.

DiVito, L., & Ingen-Housz, Z. (2021). From individual sustainability orientations to collective sustainability innovation and sustainable entrepreneurial ecosystems. Small Business Economics, 56(3), 1057–1072.

European Commission. (2022). Regional Competitiveness Index 2.0—2022 edition. European Union. Retrieved April 7, 2024, from https://ec.europa.eu/regional_policy/information-sources/maps/regional-competitiveness_en.

Fichter, K., & Clausen, J. (2016). Diffusion dynamics of sustainable innovation—Insights on diffusion patterns based on the analysis of 100 sustainable product and service innovations. Journal of Innovation Management, 4(2), 30–67.

Feld, B. (2020). Startup communities: Building an entrepreneurial ecosystem in your city. John Wiley & Sons.

Fritsch, M., & Storey, D. J. (2014). Entrepreneurship in a regional context: Historical roots, recent developments and future challenges. Regional studies, 48(6), 939-954.

Fritsch, M., & Wyrwich, M. (2018). Regional knowledge, entrepreneurial culture, and innovative start-ups over time and space—An empirical investigation. Small Business Economics, 51, 337–353.

Franzese, R., & Kam, C. (2009). Modeling and interpreting interactive hypotheses in regression analysis. University of Michigan Press.

Greenacre, M., Groenen, P. J. F., Hastie, T., d'Enza, A. I., Markos, A., & Tuzhilina, E. (2022). Principal component analysis. Nature Reviews Methods Primers, 2(1), 100.

Hall, J. K., Daneke, G. A., & Lenox, M. J. (2010). Sustainable development and entrepreneurship: Past contributions and future directions. Journal of Business Venturing, 25(5), 439–448.

Hájek, P., & Stejskal, J. (2018). R&D cooperation and knowledge spillover effects for sustainable business innovation in the chemical industry. Sustainability, 10(4), 1064.

Hassink, R. (2005). How to unlock regional economies from path dependency? From learning region to learning cluster. European planning studies, 13(4), 521-535.

Hess, S., Wahl, A., & Johnson, A. R. (2025). Measuring entrepreneurial ecosystems across levels: a district approach. Small Business Economics, 1-33.

Hoogendoorn, B., Van der Zwan, P., & Thurik, R. (2019). Sustainable entrepreneurship: The role of perceived barriers and risk. Journal of Business Ethics, 157, 1133–1154.

IAB/ZEW Start-up Panel. (2021). IAB and ZEW, Nürnberg and Mannheim, Germany. Retrieved October 20, 2022, from https://www.gruendungspanel.de/en/zew-start-up-panel/home.

Isenberg, D. J. (2010). How to start an entrepreneurial revolution. Harvard Business Review, 88(6), 40–50.

Jolliffe, I. T. (2002). Choosing a subset of principal components or variables. In Principal component analysis (pp. 111–149). Springer.

Jolliffe, I. T., & Cadima, J. (2016). Principal component analysis: A review and recent developments. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 374(2065), 20150202.

Kallis, G., Kostakis, V., Lange, S., Muraca, B., Paulson, S., & Schmelzer, M. (2018). Research on degrowth. Annual review of environment and resources, 43(1), 291-316.

Leendertse, J., Schrijvers, M., & Stam, E. (2022). Measure twice, cut once: Entrepreneurial ecosystem metrics. Research Policy, 51(9), 104336.

Leeuw, J. de, & Meijer, E. (2008). Introduction to multilevel analysis. In Handbook of multilevel analysis (pp. 1–75). Springer.

Muñoz, P., & Cohen, B. (2018). Sustainable entrepreneurship research: Taking stock and looking ahead. Business Strategy and the Environment, 27(3), 300–322.

North, D. C. (1990). Institutions, institutional change and economic performance. Cambridge University Press.

OECD. (2018). OECD science, technology and innovation outlook 2018: Adapting to technological and societal disruption. OECD Publishing https://doi.org/10.1787/sti_in_outlook-2018-en.

O'Shea, G., Farny, S., & Hakala, H. (2021). The buzz before business: A design science study of a sustainable entrepreneurial ecosystem. Small Business Economics, 56, 1097–1120.

Pankov, S., Velamuri, V. K., & Schneckenberg, D. (2021). Towards sustainable entrepreneurial ecosystems: Examining the effect of contextual factors on sustainable entrepreneurial activities in the sharing economy. Small Business Economics, 56, 1073–1095.

Parrish, B. D. (2010). Sustainability-driven entrepreneurship: Principles of organization design. Journal of Business Venturing, 25(5), 510–523.

Raposo, M., Fernandes, C. I., & Veiga, P. M. (2022). We dreamed a dream that entrepreneurial ecosystems can promote sustainability. Management of Environmental Quality: An International Journal, 33(1), 86–102.

Roundy, P. T., Bradshaw, M., & Brockman, B. K. (2018). The emergence of entrepreneurial ecosystems: A complex adaptive systems approach. Journal of Business Research, 86, 1–10.

Schaltegger, S., & Wagner, M. (2011). Sustainable entrepreneurship and sustainability innovation: Categories and interactions. Business Strategy and the Environment, 20(4), 222–237.

Schaper, M. (2016). Understanding the green entrepreneur. In Making ecopreneurs (pp. 7-20). Routledge.

Schulz, C., & Bailey, I. (2014). The green economy and post-growth regimes: opportunities and challenges for economic geography. Geografiska Annaler: Series B, Human Geography, 96(3), 277-291.

Schulz, C., & Braun, B. (2021). Post-growth perspectives in Economic Geography. DIE ERDE–Journal of the Geographical Society of Berlin, 152(4), 213-217.

Shepherd, D. A., & Patzelt, H. (2011). The new field of sustainable entrepreneurship: Studying entrepreneurial action linking "what is to be sustained" with "what is to be developed." Entrepreneurship Theory and Practice, 35(1), 137–163.

Shepherd, D. A., Patzelt, H., & Haynie, J. M. (2010). Entrepreneurial spirals: Deviation—Amplifying loops of an entrepreneurial mindset and organizational culture. Entrepreneurship Theory and Practice, 34(1), 59–82.

Shepherd, D. A. (2011). Multilevel entrepreneurship research: Opportunities for studying entrepreneurial decision making. Journal of Management, 37(2), 412–420.

Spigel, B. (2017). The relational organization of entrepreneurial ecosystems. Entrepreneurship Theory and Practice, 41(1), 49–72.

Spigel, B., & Stam, E. (2018). Entrepreneurial ecosystems. In SAGE handbook of entrepreneurship and small business (p. 21). Sage.

Spiekermann, K., & Neubauer, J. (2002). European accessibility and peripherality: Concepts, models, and indicators. Nordregio.

Stam, E. (2015). Entrepreneurial ecosystems and regional policy: A sympathetic critique. European Planning Studies, 23(9), 1759–1769.

Stam, E., & Spigel, B. (2016). Entrepreneurial ecosystems. USE Discussion Paper Series.

Stam, E. (2017). Measuring entrepreneurial ecosystems. In Entrepreneurial ecosystems: Place-based transformations and transitions (pp. 173–197). Springer.

Stam, E., & Van de Ven, A. (2021). Entrepreneurial ecosystem elements. Small Business Economics, 56(2), 809–832.

Stam, E., & Welter, F. (2020). Geographical contexts of entrepreneurship: Spaces, places, and entrepreneurial agency. In The Psychology of Entrepreneurship (pp. 263–281). Routledge.

Stuart, T. E., & Sorenson, O. (2007). Strategic networks and entrepreneurial ventures. Strategic Entrepreneurship Journal, 1(3–4), 211–227.

Takyi, L., & Naidoo, V. (2020). Innovation and business sustainability among SMEs in Africa: The role of the institutions. In Sustainability in the entrepreneurial ecosystem: Operating mechanisms and enterprise growth (pp. 50–74). IGI Global.

Theodoraki, C., Dana, L. P., & Caputo, A. (2022). Building sustainable entrepreneurial ecosystems: A holistic approach. Journal of Business Research, 140, 346–360.

Tiba, S., van Rijnsoever, F. J., & Hekkert, M. P. (2021). Sustainability startups and where to find them: Investigating the share of sustainability startups across entrepreneurial ecosystems and the causal drivers of differences. Journal of Cleaner Production, 306, 127054.

Torres Valdés, R. M., Lorenzo Álvarez, C., Castro Spila, J., & Santa Soriano, A. (2019). Relational university, learning and entrepreneurship ecosystems for sustainable tourism. Journal of Science and Technology Policy Management, 10(4), 905–926.

Unger, J. M., Rauch, A., Frese, M., & Rosenbusch, N. (2011). Human capital and entrepreneurial success: A meta-analytical review. Journal of Business Venturing, 26(3), 341–358.

Volkmann, C., Fichter, K., Klofsten, M., & Audretsch, D. B. (2021). Sustainable entrepreneurial ecosystems: An emerging field of research. Small Business Economics, 56(3), 1047–1055.

Voulvoulis, N., Giakoumis, T., Hunt, C., Kioupi, V., Petrou, N., Souliotis, I., & Vaghela, C. J. G. E. C. (2022). Systems thinking as a paradigm shift for sustainability transformation. Global Environmental Change, 75, 102544.

Weiß, R., Fichter, K., & Strangalies, C. (2013). Green Economy Gründungsmonitor. Borderstep Institute, Berlin.

Wurth, B., Stam, E., & Spigel, B. (2022). Toward an entrepreneurial ecosystem research program. Entrepreneurship Theory and Practice, 46(3), 729–778.

5 Empirical Paper

Meijering, B. (2025). Cycling as critical infrastructure for green start-ups: A multilevel analysis in Germany.

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Abstract

Despite physical infrastructure being known as a critical enabler of entrepreneurship- ship, cycling infrastructure and its role in entrepreneurship remain largely unexplored. However, a well-established cycling infrastructure can support green start-up activity by facilitating connectivity and the exchange of knowledge and ideas without the reliance on carbon-intensive transport, which aligns with their environmental goals. This article studies the relationship between cycling infrastructure and green start-up activity at the regional (NUTS-3) level in Germany and whether this relationship is amplified by the wider entrepreneurial ecosystem (EE). This study is virtually the first to examine how a well-established cycling infrastructure is conducive to start-up activity. With firm-level data from the IAB/ZEW Start-up Panel, multilevel regression models are used to account for differences in green start-up activity across urban, intermediate, and rural regions. The findings show a strong significant, and positive relationship between cycling infrastructure and green start-up activity at the regional level, even after including various controls. However, this relationship is not amplified by the wider ecosystem. In the transition towards a Green Economy, policymakers should invest in cycling infrastructure because of its supportive role towards green start-ups.

Keywords: cycling; green start-ups; sustainability.

5.1 Introduction

Despite that cycling is well-known as a solution to a variety of mobility-related problems in cities and regions, including environmental issues, such as pollution and transport carbon emissions [1,2], it remains largely unexplored in the field of entrepreneurship. This is surprising for two related reasons.

First, physical infrastructure is generally seen as a critical enabler of entrepreneurship-ship [3]. It fosters connectivity between individuals and the exchange of knowledge and ideas [4]. This idea is well reflected in one of the current most popular concepts in the field of entrepreneurship: the concept of entrepreneurial ecosystems (EEs). This concept sheds light on how ten interdependent contextual (f)actors, for example, physical infrastructure and knowledge, foster growth-oriented entrepreneurship in a given territory [5]. However, physical infrastructure has often been measured through air and motorway transport in EE studies [6–9].

This brings us to the second reason. Not only does a well-developed cycling infrastructure facilitate connectivity as well, but traditional metrics of physical infrastructure in EE studies are also not conducive to every type of entrepreneurship. Environmental concerns linked to air and motorway transport can be a potential barrier to certain types of entrepreneurship. This becomes particularly apparent with green start-ups. Green start-ups, defined as ventures under eight years old that place ecological sustainability at the core of their business model, attach particular importance to operating in green contexts [10]. Cycling-friendly cities and regions can support green start-up activity by facilitating connectivity without the reliance on carbon-intensive transport, which aligns with their environmental goals.

While in response to the lack of sustainability in the traditional EE concept, a novel concept has emerged, so-called sustainable entrepreneurial ecosystems (SEEs), virtually no study has yet explored how cycling infrastructure fosters green start-up activity. SEEs are ecosystems designed to foster entrepreneurship that places environmental and/or social sustainability at the core of the business model [11]. However, previous SEE studies have been limited to sustainable orientation in institutional settings [12], within actor networks, on the customer side [13], within stakeholder support and collaboration [14], and university-related support programs [15].

The objective of this study is twofold. First, this study explores the relationship between cycling infrastructure and green start-ups at the regional (NUTS-3) level (see definition of NUTS-3 regions in Section 5.3.2) in Germany. Second, this study investigates whether this effect is amplified by the wider ecosystem, referring to all other ecosystem resources and institutions, aside from physical infrastructure, which are specifically defined in Section 5.3.2. After all, physical infrastructure can serve as a gateway, enabling entrepreneurs to access a wider ecosystem of institutions and resources, for example, networks, knowledge, and human capital. Without these connections, infrastructure risks remain an isolated resource rather than a driver of entrepreneurship [16]. With data from the IAB/ZEW Start-up Panel (2021) [17], multilevel regression models are used. This helps account for differences in green start-up activity across urban, intermediate, and rural regions, reducing the influence of regional disparities on the results. Also, control variables related to public transportation systems; quality of life (QoL) (i.e., population-employment density, population growth, amenities and the creative class); and the regional business structure are included that could otherwise interfere with the studied relationships.

This study makes an important contribution to the entrepreneurship literature. It is virtually the first study that explores the relationship between start-up activity and cycling infrastructure. As economic considerations often drive infrastructure investments among policymakers, the finding that cycling-friendly regions are significantly conducive to green start-up activity is an important one. With current challenges such as climate change, investing in cycling infrastructure is important to accelerate the transition towards a Green Economy through its supporting role to green start-ups.

The remainder of this article is structured as follows. In Section 4-2, the literature review and hypotheses are discussed. Section 5.3 focuses on the data and methods. Hereinafter, the results are discussed in Section 5.4. Finally, Section 5.5 includes the conclusion and discussion.

5.2 Literature Review

5.2.1 Definition of sustainable entrepreneurship

Sustainable entrepreneurship is defined as a process of “discovering, creating, and exploiting entrepreneurial opportunities that generate social and environmental benefits to communities to promote sustainability” [18] (p. 1). It distinguishes from traditional entrepreneurship in that social and environmental protection are at the core instead of purely economic goals [19]. As “companies are considered by many to be the main players creating environmental and social problems and thus to be the source of a lack of sustainability in society”, sustainable entrepreneurship is important in the transition towards a sustainable economy [10] (p. 222).

Defining green (eco-)start-ups

However, the theoretical boundaries between sustainable entrepreneurship and the related concepts of green (eco-) and social entrepreneurship are quite blurry [19]. While social entrepreneurship centres on solving societal problems, green (eco-)entrepreneurship centres on solving environmental issues. As discussed earlier, this study focuses on green (eco-)entrepreneurship.

Green (eco-)entrepreneurship refers to any entrepreneurial activity that results in an ab-absolute reduction in environmental impacts, also within traditional markets [10]. The entrepreneurial challenge is to achieve economic success through the provision of products and services, all while minimizing environmental impacts. Green (eco-)entrepreneurship can emerge in established ventures (incumbents), emerging and young ventures (start-ups), as well as nascent entrepreneurs who are in the process of developing new businesses. However, start-ups are said to have the strongest impact on the transition towards a Green Economy [20]. In Schumpeter's seminal work in 1934 [21], start-ups were identified as a key force in innovation and transformation. To be labelled as "green", businesses must align with the Triple Bottom Line, prioritizing products (goods or services) that generate positive environmental impacts and support Green Economy objectives. The green nature of start-ups is primarily defined by three key aspects of their business:

- Product-related characteristics—Do the start-up's products (goods or services) align with environmental goals? This includes areas like renewable energy, resource efficiency, circular economy, waste management, emission reduction, and biodiversity protection.
- Entrepreneur-related characteristics—How do entrepreneurs themselves shape the greenness of their start-ups? This involves their motivation [10], values [22], and attitudes [23] on environmental issues in the business. Additionally, the environmental-related qualifications and knowledge of the entrepreneur can be considered relevant [24].
- Strategy-related characteristics—How can strategy, through (continuous) interaction with external stakeholders, strengthen or weaken the greenness of the start-up? This is decided by external stakeholders, such as investors, suppliers, and customers.

5.2.2 The current state of the art: Sustainable entrepreneurial ecosystems (SEEs)

The context of entrepreneurship plays a crucial role in strengthening or weakening the trajectory of green businesses. This idea dates back to Welter [25], who argued that entrepreneurship does not take place in a vacuum but in particular contexts. Contexts are formative for entrepreneurship in that they enable or constrain entrepreneurship [26]. While contexts are multifarious, the geographical context is an important one. This is well reflected in the popular concept of entrepreneurial ecosystems (EEs) [26]. An EE is defined as a set of ten interdependent contextual (f)actors that enable productive entrepreneurship within a given territory [5]. The contextual (f)actors range from resource endowments (e.g., physical infrastructure, knowledge, and human capital) to institutional arrangements (e.g., formal institutions and culture) [27]. However, an EE is centred around traditional growth-oriented entrepreneurship and pays little attention to sustainable entrepreneurship [28,29]. This has raised the question of how ecosystems can support sustainable entrepreneurship.

In response to this, a novel wave of ecosystem research has emerged around sustainable entrepreneurial ecosystems (SEEs) that centre around the question of how contexts support sustainable entrepreneurship, both environmental and/or social sustainability. Thus far, SEE studies have investigated interactions among entrepreneurial actors [13], the role of credibility and sharing ventures in sustaining a sustainable economy [12], and the development of opportunities within SEEs [30]. Other research has analyzed perceptions of SEE strength in specific regions [14] and the impact of university-related support programs on sustainable regional development through knowledge spillovers [15].

However, physical infrastructure has received less attention in empirical SEE studies thus far, whereas it plays a crucial role in enabling entrepreneurs to connect with suppliers, customers, and other ecosystem (f)actors [31]. Conversely, can an SEE truly be considered “sustainable” if little attention has been paid to how entrepreneurship and contextual (f)actors are connected through the available physical infrastructure? Even with abundant resources, such as funding, mentorship, and collaborative spaces, their impact on entrepreneurship may be limited if infrastructure fails to support access and seamless integration into the ecosystem. Since physical infrastructure is crucial for the functioning of (S)EEs, we need to improve our understanding of what kinds of physical infrastructure support sustainable entrepreneurship.

Although it remains unclear if traditional EEs can foster sustainable entrepreneurship as well and to what extent EEs and SEEs are overlapping concepts or complementary fields [11], the environmental concerns with traditional metrics of physical infrastructure in EE studies call their applicability to green entrepreneurship into question. Much of the physical infrastructure metrics in traditional EE studies are centred around air or motorway transport [6–9]. While these metrics do reflect economic connectivity, they largely overlook environmental impacts. High reliance on motorway and air transport contributes significantly to climate change, air pollution, and resource depletion [32] – challenges that contradict the sustainability objectives of green start-ups. Given the growing urgency of climate change, there is a need to integrate environmentally conscious metrics of physical infrastructure in studies of SEEs to align with the environmental goals of green enterprises.

Cycling as critical infrastructure for green start-ups

The growing demand for cycling is a reflection of the realization of the limitations of automobile-dependent transport planning, on the one hand, in terms of traffic congestion, road traffic injury, parking problems, reduced levels of amenity and liveability, and wider issues of public health [2], and on the other hand, concerning air pollution, resource depletion, and climate change [33]. Although the literature on the impacts of cycling infrastructure on entrepreneurship is limited to date, cycling can be seen as a critical infrastructure for green start-ups for three main reasons. The first reason relates to environmental considerations, the second to direct economic advantages, and the third to personal (lifestyle) considerations.

First, cities and regions that invest in cycling infrastructure support environmentally responsible economic activity by decarbonizing mobility systems. Cycling facilitates connectivity and the exchange of knowledge and information without reliance on carbon-intensive transport, which is essential for green business formation and growth.

Second, direct economic advantages are also a key consideration. Cycling is highly cost-efficient. Compared to other alternative modes of transportation (e.g., public transportation), cycling requires minimal direct user costs [34], which is particularly advantageous for start-ups that are often budget-constrained [35]. In addition, businesses located in areas with a well-established cycling infrastructure are found to gain more profit from local customers than those in auto-centric areas – although this relationship persists particularly in urban downtowns and retail corridors. A study showed that cyclists and pedestrians spend more per month than visitors who arrive by car [36]. Thus, non-auto-centric businesses might economically benefit from cycling-friendly cities.

Third, there are also personal (lifestyle) considerations that attract green start-ups to cycling-friendly cities and regions. Both the founders and labour force of green start-ups are inclined to be located in environments that demonstrate a certain commitment to sustainability [37], which can be reflected in cycling-friendly areas. This is driven by personal values in which they advocate for local sustainability. However, highly educated professionals, often employed in sustainable businesses [38], also show a desire to pursue an active and healthy lifestyle through cycling, particularly in the context of Germany [39]. This further demonstrates why green start-ups often prefer a location in cycling-friendly cities and regions. Building on these arguments, the following hypothesis is tested:

Hypothesis 1. *The share of cycling infrastructure is positively associated with green start-up activity at the regional level.*

Cycling and the connection to the wider ecosystem

Despite this, cycling infrastructure risks becoming an isolated resource rather than a catalyst for entrepreneurship without connections to the broader ecosystem [16]. Ecosystems function as complex, interconnected systems where entrepreneurs, institutions, networks, and resources like physical infrastructure dynamically interact to drive business formation and growth [5]. In isolation, the elements of an ecosystem may have little impact on entrepreneurship. For example, investments in innovation hotspots without the necessary cultural and social support have resulted in empty real estate rather than thriving centres of innovation [40]. While physical infrastructure alone may not directly drive entrepreneurship, it can play a crucial indirect role by connecting start-ups to essential resources and institutions within the ecosystem. When integrated into the wider ecosystem, cycling infrastructure can significantly enhance its impact on green start-ups – not only by facilitating physical movement but also by fostering meaningful engagement with key actors and resources, such as knowledge hubs, incubators, accelerators, and networks. Therefore, understanding whether the wider ecosystem amplifies the impact of cycling infrastructure on green start-ups is crucial.

However, it remains unclear in what kinds of ecosystems sustainable entrepreneurship, e.g., green start-ups, is engaged. Are these EEs, SEEs, or a combination of both? Since it is unknown whether traditional EEs can also foster sustainable entrepreneurship, the first step is to determine whether ecosystems that are successful in fostering traditional, growth-oriented entrepreneurship also work in fostering sustainable entrepreneurship [11]. Evidence already suggests that the rates of traditional entrepreneurship correlate with the rates of social entrepreneurship at a country level [41]. Are these findings also transferable to green start-ups? With the second hypothesis, the interaction effect between cycling infrastructure and the wider, traditional EE on green start-up activity is tested:

Hypothesis 2. *The positive association between the share of cycling infrastructure and green start-up activity at the regional level is amplified by the wider EE.*

5.3 Data and Methods

5.3.1 Firm-level data

This study uses firm-level data from the IAB/ZEW Start-up Panel, IAB and ZEW, Nürnberg and Mannheim, Germany [17]. While this panel covers data from 2008 to 2021, information on the environmental objectives of start-ups is only available for 2018 and 2021. This study uses data from 2021 (reference year: 2020) on 6776 start-ups, mainly to avoid a time lag with the regional data. Start-ups are defined as firms younger than eight years old. The data cover all industries, excluding agriculture, mining and quarrying, electricity, water and gas supply, health care, and the public sector. Annual surveys are conducted once a year with computer-aided telephone interviews (CATIs). The entities are legally independent firms run by at least one full-time entrepreneur; de-merger foundations and subsidiaries are not considered in the panel. The data cover information related to the entrepreneur(s) and the firm, including the headquarters office at the regional (NUTS-3) level.

Dependent Variables

The panel uses two definitions of green start-ups based on energy and overall CO_2 reduction that are product-related as well as strategy-related (see Section 5.2.1). In the annual survey, start-ups were asked if they slightly (2 = yes, low); significantly (1 = yes, significant); or not at all (0 = no) reduced their energy consumption and/or overall CO_2 within the company (strategy-related) and/or on the customer side (product-related). This study captures start-ups that only significantly did so because environmental protection takes a more central role in their business models [10]. The dependent variables are formulated as follows:

- The first dependent variable measures the number of start-ups that significantly reduced energy consumption and/or the overall CO_2 balance in the company at the regional (NUTS-3) level;
- The second dependent variable measures the number of start-ups that significantly reduced energy consumption and/or the overall CO_2 balance on the customer side at the regional (NUTS-3) level.

Sample

Information on green start-ups at the regional (NUTS-3) level was aggregated to a sample of 390 regions – from the 401 regions in the year 2020 – due to firm-level data availability. From the initial 6776 start-ups, 1007 start-ups significantly reduced energy consumption and/or the overall CO_2 balance in the company, while 1573 start-ups did so on the customer side. Figure 5-1 shows the spatial distribution of green start-ups with internal green practices, while Figure 5-2 illustrates those with customer-focused external green practices. In general, there are more green start-ups with external green practices than there are start-ups with internal green practices. In both Figures 5-1 and 5-2, green start-up activity is not as strong as expected in North Rhine-Westphalia, the most populated federal state of Germany, and quite strong in Bayern instead.

5.3.2 Region-level data

The region-level data are linked to aggregated firm-level data at the NUTS-3 level. An advantage of using NUTS-3 regions is that they represent the local dimension of entrepreneurship [6], on the one hand, and the measurement of many regional indicators, on the other hand. The NUTS (Nomenclature of Units for Territorial Statistics) system is a hierarchical classification of regions used by the European Union for statistical purposes. NUTS-3 regions specifically refer to the third level of this classification, which corresponds to smaller, more localized administrative regions within a country (see https://ec.europa.eu/eurostat/web/nuts, accessed on 30 January 2025).

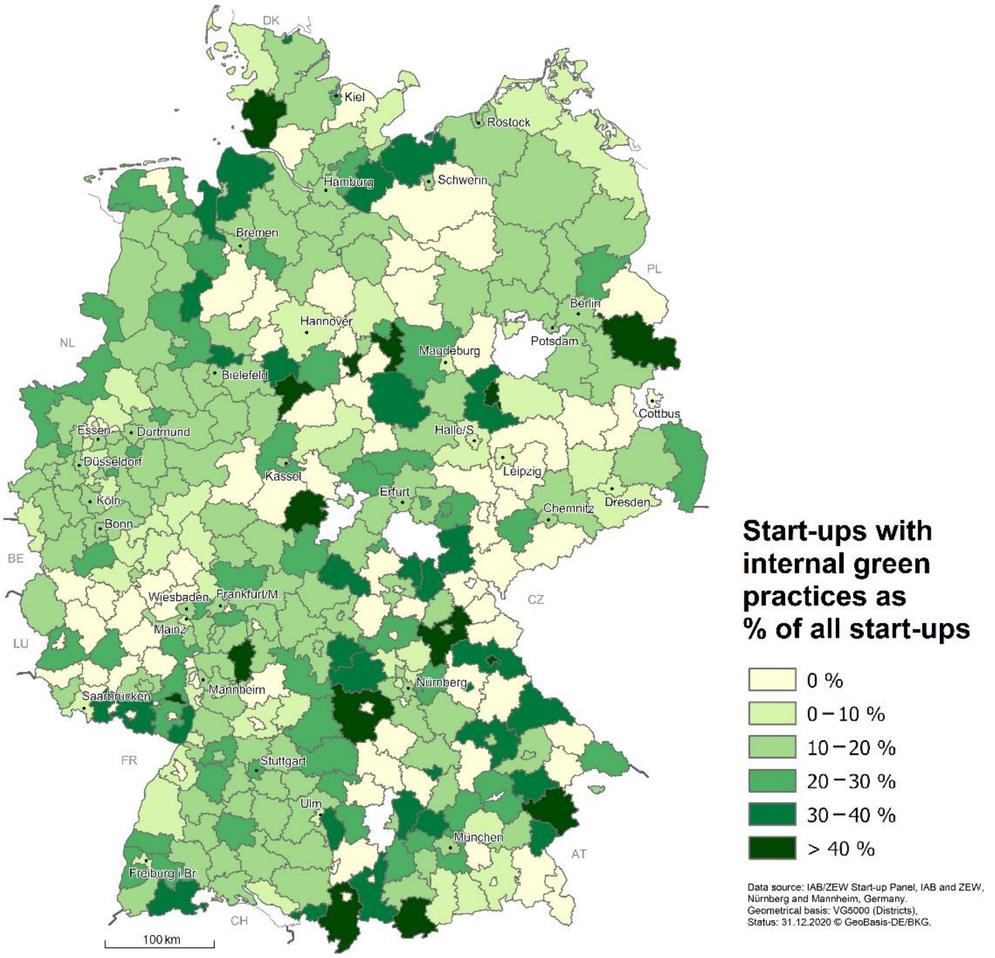


FIGURE 5-1. Green start-ups with energy and/or overall CO_2 reduction in the company across Germany. Data source: IAB/ZEW Start-up Panel [17].

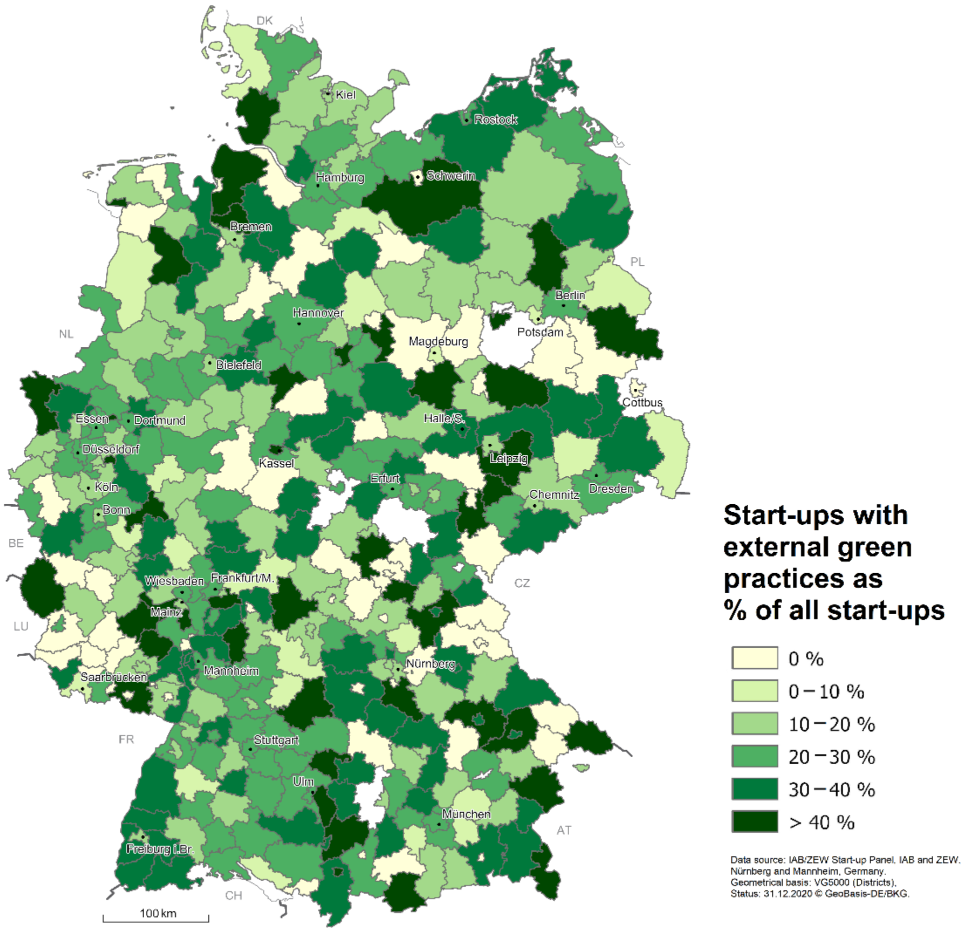


FIGURE 5-2. Green start-ups with energy and/or overall CO_2 reduction on the customer side across Germany. Data source: IAB/ZEW Start-up Panel [17].

Measurement of cycling infrastructure

There is a great demand for data on cycling infrastructure because such information is crucial to enhancing safe cycling and encouraging cycling as a sustainable mode of transport. Until recently, no official source provided this kind of information at the regional level on a European scale. Lately, the European Cyclists' Federation (ECF) has established a dataset that quantifies different kinds of cycling infrastructures (e.g., cycle tracks, cycle lanes, and cycle streets) using OpenStreetMap (OSM). This study uses the share of cycling lanes relative to the main road network in km, taking into account the directionality. Cycle lanes are used because they are a standardized form of cycling infrastructure found across most cities and regions in Germany. In contrast, other forms of cycling infrastructure, for example, cycle streets, may vary more significantly in design and implementation across Germany, making cycle lanes a more ideal metric for cross-regional studies. Cycling lanes are defined as a part of a carriageway designated for cycles only, distinguished from the rest of the carriageway by paint or other markings but without physical separation from motorized traffic. The total main road network is defined through the main arteries for motorized traffic.

While the first edition of the ECF tracker 1.0 represents data for 500+ European cities, the second edition of the ECF tracker 2.0 (2024) [42] expanded the methodology to cover peri-urban and rural areas as well. Although an advantage of the second edition is that it covers all regions in Germany, there is a clear time lag with the firm-level data (reference year: 2020), which is problematic. Cycling infrastructure in Germany has experienced notable developments within four years; for example, it has been influenced by national strategies, such as the National Cycling Plan 3.0 (NCP 3.0), introduced in 2020. To deal with this endogeneity issue, the ECF tracker 2.0 data were cross-referenced with the oldest ECF tracker 1.0 from 2022, which was possible for 66 German cities due to data availability. A pairwise *t*-test showed that there is no meaningful significant difference between the two years ($p = 0.715$). Thus, data from the ECF tracker 2.0 can be used unproblematically as a measure of the regional quality of cycling infrastructure in 2020 due to no extreme fluctuations over time.

Controlling for other modes of transportation

Public transport systems are an important control when studying cycling infrastructure because they often interact with cycling or walking as a complementary form of mobility, unlike motorway or air transport [43]. Research has shown that the presence of accessible public transport systems can encourage individuals to cycle, as they may use bicycles for short trips and rely on public transport for longer journeys [44]. It is essential to account for public transport systems to accurately isolate the effects of cycling infrastructure itself, without confounding influences. In this study, public transportation is measured by the average inhabitant-weighted linear distance to the nearest public transport stop (buses, trams, and trains). The data cover stops with at least 20 departures, and distances were calculated in a 100 × 100 m grid (BBSR, 2021) [45].

Controlling for quality of life

Simultaneously, a well-established cycling infrastructure could be representative of the regional quality of life (QoL). The quality of life in cities and regions is defined as the overall conditions that contribute to the well-being of a community [46]. To avoid omitted variable biases—where unaccounted factors, such as the regional QoL, distort the relationship between cycling infrastructure and green start-ups—it is essential to control for confounding factors in the analysis. Jacobs' (1961) promotion of a dense, socially and economically diverse environment has greatly influenced recent studies on quality of life, reclaiming vibrant and healthy cities and regions [47]. Here, density indicators as well as metrics of amenities and the creative class are important to measure socially and economically vibrant regions. Building on Jacobs' work (1961) [47], the following QoL indicators are used in this study:

- Population-employment density (measured by the population and employees at the workplace per km2);
- Population growth (measured in percentage over five years);
- Amenities (measured by the proportion of inhabitants with a max. 1000 m distance to the nearest supermarket or discounter);
- Creative class (measured by the percentage of employees in the creative and cultural industries).

Measurement of entrepreneurial ecosystems (EEs)

Table 1 represents the definitions and measurements of the wider EE, consisting of nine elements. Physical infrastructure is not included because it is already represented by cycling infrastructure. The operationalization of the elements is based on common metrics [9,27]. Due to data availability, a few elements in the dataset exhibit a time lag of up to three years (see Table 1). The elements in Table 1 build the wider ecosystem, calculated with a Principal Component Analysis (PCA) as a dimensionality reduction technique. All variables were standardized according to z-scores to ensure comparability. Five PCA components were extracted into one final variable, with a total cumulative proportion of 0.756 based on the "elbow rule" [48].

TABLE 5-1. Definition and operationalization of the wider EE.

Indicators	Definition	Measurement in Time <>	NUTS Level	Source and Data Availability <>
Formal institutions	The rules and regulations in society	Quality of Government Index based on the level of corruption, unaccountability, and impartiality <2021>	NUTS-2	Quality of Government Index by the Quality of Government Institute (University of Gothenburg) in the RCI (2022) [49]

Entrepreneurial culture	The extent to which entrepreneurship is appreciated in society	Percentage of self-employed per 100 members of the workforce <2020>	NUTS-3	Ongoing spatial monitoring of the BBSR (2000–2023) [50]
Networks	The connectedness of businesses for new value creation	Percentage of SMEs with innovation cooperation activities <2021>	NUTS-2	Regional Innovation Scoreboard (DG GROW) in the RCI (2022) [49]
Market demand	The availability of financial resources within the population to purchase goods and services	GDP per capita <2020>	NUTS-3	Ongoing spatial monitoring of the BBSR (2000–2023) [50]
Intermediaries	Services that facilitate the creation, development, and growth of new businesses	Indirect federal grants for R&D projects in 1000 EUR per member of the working-age population <2017>	NUTS-3	Ongoing spatial monitoring of the BBSR (1991–2017) [50]
Talent	The skills, knowledge, and experience held by individuals	Percentage of students at universities and universities of applied sciences per 1000 inhabitants <2020>	NUTS-3	Ongoing spatial monitoring of the BBSR (2006–2021) [50]
Knowledge	Investments in knowledge (both scientific and technological)	Intramural R&D expenditure as % of GDP <2019>	NUTS-2	Eurostat, Regional Science and Technology Statistics in the RCI (2022) [49]
Leadership	The presence of leaders who guide and direct collective action	EU research framework program H2020 in 1000 EUR per member of the working-age population <2017>	NUTS-3	Ongoing spatial monitoring of the BBSR (2014–2017) [50]
Finance	The presence of financial means to invest in business activities	Percentage of start-ups that received external financial support in loans, venture capital, or funds at least once <2018–2020>	NUTS-3	IAB/ZEW Start-up Panel (2021) [17]

Controlling for the regional business structure

The regional business structure could simultaneously influence green start-up activity in the region. To control for this, firm characteristics derived from all start-ups in the IAB/ZEW Start-up Panel (2021) [17] were aggregated at the regional level. Green start-up activity can be higher in regions dominated by large firms (measured in terms of workforce and revenue) because of the enriching effects of partnerships with established firms [51]. Simultaneously, firm age negatively influences the environmental orientation in firms [52]. The older firms averagely are in a region, the less environmentally oriented they tend to be. Also, the in-house R&D in a region is found to be representative of the sustainable performance of local firms, aside from innovation [53]. Lastly, regions dominated by manufacturing industries often represent high carbon footprints and a lack of sustainable orientation in the local firms [54].

5.3.3 Classification of region types

Since green start-up activity might point to differences between urban, intermediate, and rural regions in Germany, a multilevel model is used across different levels of region types. The classification of NUTS-3 regions in urban, intermediate, and rural regions is based on the concentration of the population, jobs, and the geographical proximity to these areas (BBSR, 2021) [45]. Geographical proximity was measured using the BBSR accessibility model. The centrality index of the accessibility model cumulates the daily population (inhabitants plus inbound commuters minus outbound commuters) that can reach settlement centres within two hours of travel time by motorized private transport. The data consist of 211 urban, 84 intermediate, and 95 rural regions.

5.3.4 Model

Multilevel linear regression models with random intercepts were used to allow the error term to differ across the three levels of the region types. Different types of regions can have unique baseline effects on the outcome (i.e., the number of green start-ups), driven by contextual factors [55]. Random intercepts capture these differences, preventing biased estimates of the relationships. Within the model, a two-way interaction term was included to model how the effect of the share of cycling infrastructure on the outcome changes depending on the wider ecosystem. Two models were created for the two dependent variables, where:

$$Y_{ij} = \beta_0 + \sum_{k=1}^{K} \beta_k X_{ik} + Q(X_{i1} \cdot Z_j) + u_j + \epsilon_{ij} \qquad (1)$$

- Y_{ij} is the number of green start-ups for i-region in the j-region type;
- β_0 is the fixed intercept, representing the overall baseline rate of green start-ups;
- $\sum_{k=1}^{K} \beta_k X_{ik}$ is the summation of K predictor variables (X_{ik}) for the i-region, each with its fixed effect coefficient β_k;
- Q is the coefficient of the interaction term, capturing how the effect of X_{i1} on Y_{ij} changes depending on Z_j;
- u_j is the random intercept for the j-region type, capturing deviations of the j-region type's intercept from the overall intercept β_0;
- ϵ_{ij} is the residual error term for the i-region within the j-region type, capturing deviations of observed Y_{ij} from the predicted value after accounting for fixed and random effects.

5.3.5 Descriptive statistics

Table 5-2 represents the descriptive statistics. Prior to the analysis, all continuous independent variables were standardized. By standardizing the continuous variables using z-scores, the influence of outliers was mitigated in the analysis. The descriptive statistics of the standardized variables are represented in Table 5-7 in the Appendix. The variance inflation factor (VIF) was calculated to control for multicollinearity in Table 5-7 in the Appendix. There is no concerning level of multicollinearity (mean = 1.473).

TABLE 5-2. Descriptive statistics (n = 390).

Descriptive Statistics	Mean	St. Dev.	Min	Max
Firm size (employees) (mean)	3.324	4.889	0.000	80.500
Firm size (turnover) (mean)	7.871×10^{11}	1.554×10^{13}	0.000	3.070×10^{14}
In-house R&D (mean)	15,406.750	25,099.650	0.000	200,000.000
Manufacturing industries (mode)	0.697	0.460	0.000	1.000
Firm age (mean)	2.076	0.699	0.000	5.333
Creative class	2.520	2.132	0.415	16.048
Amenities	1177.731	547.731	328.000	2987.000
Population-employment density	794.764	1094.981	47.660	7679.780

Population growth	0.857	2.277	−6.609	8.565
Public transportation	583.267	579.462	144.000	6978.000
Cycle lanes	8.482	58.104	0.000	850.310
Entrepreneurial ecosystems (EEs) (PCA)	0.000	0.728	−5.123	1.056
Region type	1.703	0.835	1.000	3.000

5.4 Results

To evaluate whether a multilevel analytical approach is appropriate, Bonferroni-adjusted pairwise *t*-tests were conducted. These tests compare the means of the outcome across different levels of the grouping variable of the region types. The aim was to assess whether significant differences exist between region types. The Bonferroni-adjusted pairwise *t*-tests were computed for the first dependent variable in Table 5-3 and the second dependent variable in Table 5-4 at the 5% significance level. Both Tables 5-3 and 5-4 show significant differences in rates between urban–intermediate as well as urban-rural regions but no significant differences between intermediate–rural regions. This is also illustrated in Figure 5-3, where green start-up activity is the highest in urban and the lowest in rural regions, with no meaningful differences between rural and intermediate regions.

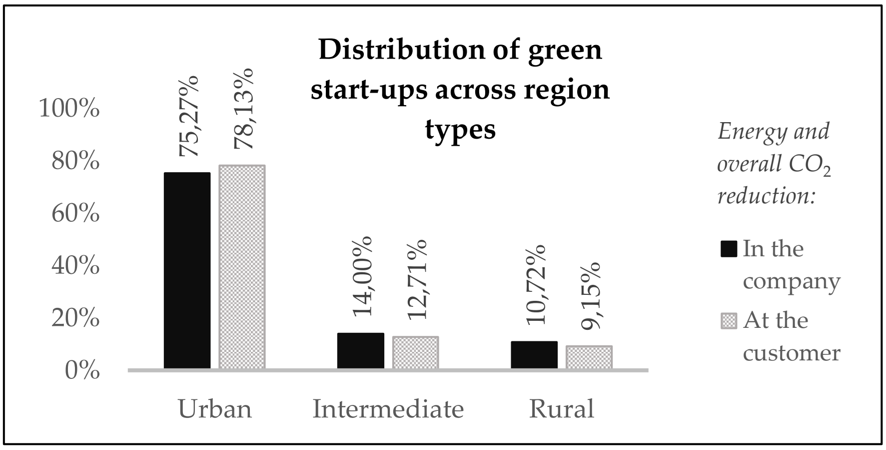


FIGURE 5-3. Distribution of green start-ups across region types.

TABLE 5-3. Bonferroni-adjusted pairwise *t*-test 1.

Pairwise *t*-tests (Bonferroni)	**Urban**	**Intermediate**
Urban	-	3.3×10^{-5} ***
Intermediate	3.3×10^{-5} ***	-
Rural	1.7×10^{-8} ***	0.84

*** = $p < 0.001$.

TABLE 5-4. Bonferroni-adjusted pairwise *t*-test 2.

Pairwise *t*-tests (Bonferroni)	**Urban**	**Intermediate**
Urban	-	4.1×10^{-6} ***
Intermediate	4.1×10^{-6} ***	-
Rural	1.3×10^{-9} ***	0.87

*** = $p < 0.001$.

As the Bonferroni-adjusted pairwise *t*-tests indicate significant differences between some region types but not others, the intraclass correlation coefficient (ICC) was calculated to assess how much of the overall variance in the outcome is explained by differences across region types. The ICC helps to further justify whether a multilevel model is appropriate. Table 5-5 represents the multilevel model for the first dependent variable: green start-ups with internal green practices. Here, the ICC is 2.52%, suggesting that only a very small proportion of the variance in green start-up activity is explained by differences across region types. Table 5-6 shows the multilevel model for the second dependent variable: green start-ups with external green practices on the customer side. The ICC is 5.42%, which suggests that differences across region types account for a moderate proportion of the variance in green start-up activity. While the random variance component is statistically significant in Table 5-6 ($p = 0.009$) but not in Table 5-5 ($p > 0.05$), a multilevel approach remains appropriate to correct for the non-independence of observations within region types. This approach ensures more precise standard errors, accounts for potential unobserved heterogeneity, and allows for meaningful comparisons across models.

TABLE 5-5. Random intercept model of the first dependent variable.

Fixed Effects				
	Estimate	**Std. Error**	**t Value**	**Pr (>|t|)**
(Intercept)	2.261	0.389	5.810	0.004
Firm size (employees) (mean)	−0.070	0.151	−0.464	0.643
Firm size (turnover) (mean)	0.060	0.149	0.404	0.686
In-house R&D (mean)	0.220	0.155	1.418	0.157
Manufacturing industries (mode)	0.274	0.338	0.811	0.418
Firm age (mean)	0.140	0.152	0.921	0.358
Creative class	0.867	0.193	4.480	0.000
Amenities	0.376	0.261	1.443	0.150
Population-employment density	1.497	0.220	6.816	0.000
Population growth	0.077	0.162	0.478	0.633
Public transportation	−0.078	0.196	−0.399	0.690
Entrepreneurial ecosystems (EEs) (PCA)	0.733	0.183	4.001	0.000
Cycle lanes	0.578	0.152	3.810	0.000
EEs X Cycle lanes	0.077	0.148	0.519	0.604
Random variance	0.218			0.127
Likelihood Ratio Test (Chisq)	134.59			$<2.2 \times 10^{-16}$
AIC	1981.8			

TABLE 5-6. Random intercept model of the second dependent variable.

Fixed Effects				
	Estimate	**Std. Error**	**t Value**	**Pr (>|t|)**
(Intercept)	3.519	0.817	4.306	0.021
Firm size (employees) (mean)	−0.073	0.253	−0.287	0.774
Firm size (turnover) (mean)	0.134	0.248	0.538	0.591
In-house R&D (mean)	0.368	0.260	1.417	0.157
Manufacturing industries (mode)	0.237	0.564	0.420	0.675
Firm age (mean)	0.148	0.254	0.585	0.559
Creative class	1.078	0.324	3.332	0.001
Amenities	0.670	0.437	1.533	0.126
Population-employment density	2.479	0.367	6.757	0.000
Population growth	0.104	0.271	0.383	0.702
Public transportation	−0.103	0.329	−0.314	0.753
Entrepreneurial ecosystems (EEs) (PCA)	1.169	0.307	3.810	0.000
Cycle lanes	0.968	0.253	3.819	0.000
EEs X Cycle lanes	0.241	0.247	0.976	0.330
Random variance	1.341			0.009
Likelihood Ratio Test (Chisq)	137.3			$<2.2 \times 10^{-16}$
AIC	2372.7			

5.4.1 Fixed effects

In both Tables 5-5 and 5-6, the regional business structure as a control is not significant. More specifically, the aggregated start-up characteristics of firm size, in-house R&D, and firm age do not influence green start-up activity in the region. Also, manufacturing industries do not influence green start-up activity in the region. However, the regional QoL seems to play a role. Creative class and population-employment density are significant and positively influence green start-up activity in the region. Densely populated regions and those with a strong presence of creative and cultural industries are leaders in drawing green start-ups. This holds for green start-ups with internal green practices (see Table 5-5) and those with external green practices on the customer side (see Table 5-6). However, amenities and population growth are insignificant. Lastly, public transportation systems do not significantly influence green start-up activity in the region. The following section tests the first hypothesis, and the section afterwards tests the second hypothesis.

Cycling infrastructure

The first hypothesis tests whether the share of cycling infrastructure is positively associated with green start-up activity at the regional level. Even after including regional controls, including public transportation systems; the quality of life (QoL) (e.g., population- employment density, population growth, amenities, and the creative class); as well as the regional business structure, there is a significant positive relationship between the share of cycling infrastructure and green start-up activity – both with internal and external green practices.

The findings in Tables 5-5 and 5-6 are also robust across different region types, ranging from urban to intermediate and rural. When start-ups engage in green activities internally and/or externally, they directly benefit from a well-established cycling infrastructure, independently from their location. For example, employees can commute more sustainably by reducing their carbon footprint, logistics can become more eco-friendly, and overall operations can better align with the environmental goals of the start-up business. While businesses might face lower consumer demand for green products in rural regions [56], Table 5-6 suggests that investments in cycling infrastructure will still translate into increased green start-up activity with external green practices on the customer side in rural, aside from intermediate and urban, regions. Figures 5-4 and 5-5 show the predictive margins. However, the relationship between green start-ups and cycling infrastructure may not be one-directional; rather, these businesses could also actively contribute to the regional adoption and reinforcement of cycling as a mode of transportation. In this sense, start-ups that integrate sustainability into their business models may also generate additional demand for sustainable mobility systems.

Figure 5-4. Predictive margins between cycle lanes and green start-up activity at the regional level (product-oriented).

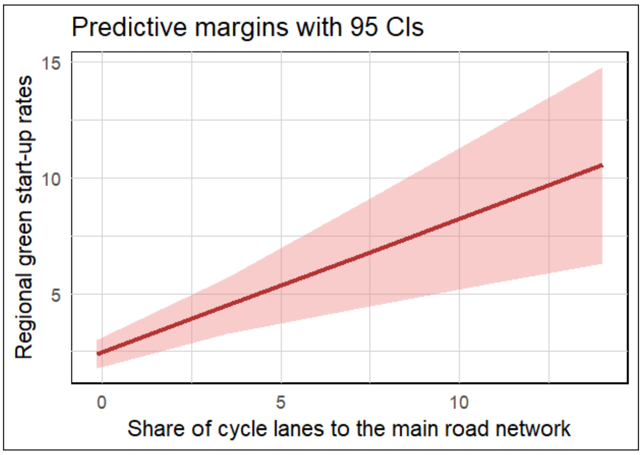
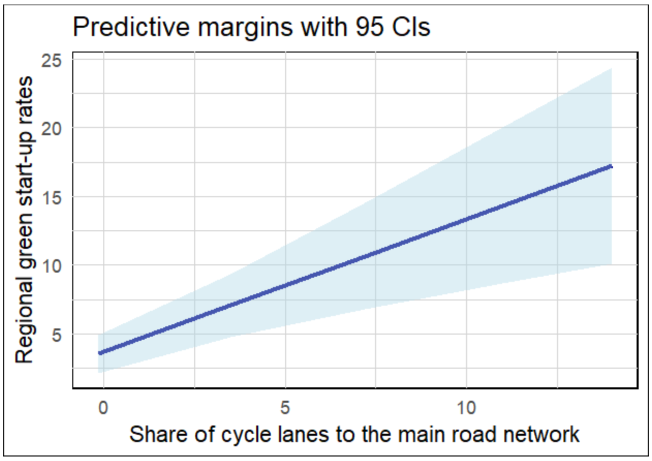


Figure 5-5. Predictive margins between cycle lanes and green start-up activity at the regional level (strategy-oriented).



Cycling infrastructure in connection to the wider ecosystem

Before testing the second hypothesis, Tables 5-5 and 5-6 show a significant and positive relationship between traditional EEs and green start-up activity in regions. This significant relationship holds for green start-ups with internal green practices (see Table 5-5) and those with external green practices on the customer side (see Table 5-6) and is also robust across different region types. This finding shows that green start-ups are not excluded from traditional, growth-oriented EEs, as often thought so [57]. Traditional EEs can still foster green start-up activity, although their support may be less strong than towards traditional, non-sustainable businesses.

The second hypothesis tests whether the positive relationship between cycling infrastructure and green start-up activity at the regional level is amplified by the wider EE. The interaction effect between cycling infrastructure and EEs is not significant in Tables 5-5 and 5-6. This suggests that cycling infrastructure, while beneficial for green start-ups, does not necessarily strengthen or weaken the role of EEs in fostering these kinds of businesses. Locations committed to sustainability may not share the same priorities as traditional EEs, which typically prioritize business growth, innovation, and competitiveness over environmental sustainability [11]. This misalignment could limit the extent to which sustainable infrastructure, such as cycling, becomes embedded within EEs. This is a notable limitation because EEs, as discussed before, support green start-ups (see Tables 5-5 and 5-6), and the integration of sustainable-focused infrastructure, such as cycling, in traditional EEs could increase connectivity and access to resources in traditional EEs for sustainable businesses.

5.5 Conclusions and Discussion

This article examined the relationship between cycling infrastructure and green start-up activity at the regional (NUTS-3) level in Germany and whether this relationship is amplified by the wider, traditional EE. This study is virtually the first to examine how a well-established cycling infrastructure is conducive to start-up activity. Multilevel linear regression models were used to account for differences in green start-up activity across urban, intermediate, and rural regions.

There is strong significant evidence that the share of cycling infrastructure is positively associated with green start-up activity at the regional level in Germany, even after including various controls related to public transportation systems, quality of life (QoL), and the regional business structure. This significant relationship is robust across urban, intermediate, and rural regions for green start-ups with internal and external green practices on the customer side. Through a well-established cycling infrastructure, green start-ups can better align their overall operations with the environmental goals of the start-up business. Simultaneously, a thriving green start-up scene may also drive demand for cycling, as sustainable businesses are often inclined to advocate for sustainability-friendly policies in cities and regions [37].

However, the effect of cycling infrastructure on green start-ups is not amplified by the traditional EE. This suggests that cycling infrastructure is not a well-embedded factor in EEs. One possible explanation for this is that locations committed to sustainability are not necessarily well-aligned with traditional EEs, whose goals are not sustainability-oriented [11]. Despite this, the results indicate that traditional EEs foster green start-up activity. This is a novel insight because few studies have addressed how traditional EEs and sustainable entrepreneurial activities relate [11]. While cycling infrastructure and EEs independently increase green start-up activity, their combined effect is not additive or synergistic.

The findings have important implications for policymakers and researchers. First, as green start-ups are not excluded from traditional EEs, and cycling is a critical infrastructure in fostering green start-up activity, policymakers and scholars should consider cycling as a way to enable connectivity between the (f)actors of EEs to mitigate environmental impacts, as opposed to common EE metrics, such as air and motorway transport [6–9]. Second, policymakers should invest more proactively in cycling infrastructure because of its positive effect on green start-up activity. In Germany, cycling infrastructure expansion is largely demand-driven, influenced by advocacy groups, petitions, and political pressure. However, demand only increases when infrastructure improves, particularly in terms of safety [58]. Since cars remain the dominant mode of transportation in Germany [59], and investments follow demand, progress remains slow, creating a possible vicious cycle. Hence, a more proactive approach is required, as seen in Denmark and the Netherlands, where cycling infrastructure is integrated into long-term urban and regional planning rather than being dependent on shifting public demand to accelerate the transition towards a Green Economy.

5.5.1 Limitations and future research

There are several limitations. First, this study used data on cycling lanes because it is the most standardized form of cycling infrastructure found across all kinds of regions in Germany. Future studies should explore how other types of cycling infrastructures (e.g., cycling streets or bike-sharing networks) are conducive to start-up activity – although this may limit the feasibility of cross-regional studies. Second, the question remains unanswered as to whether cycling is conducive to entrepreneurship in general or only to green businesses like start-ups. Are the findings transferable to other types of entrepreneurship? Third, qualitative research is needed to understand the underlying mechanisms behind the relationship between cycling and green start-ups, as well as how it could impact EEs or SEEs. Qualitative studies can help us understand why and how cycling matters, rather than merely statistically testing if it does so. Fourth, future research could use more fine-grained data and further analyze how traditional EEs, particularly, which links between the contextual (f)actors, promote green start-up activity. Fifth, the use of random-intercept models limited the ability to understand to what extent the significant relationship between cycling and green start-up activity changes across different types of regions. Future research should use random-slope models to understand this.

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Data Availability Statement: This study used data from the IAB/ZEW Start-up Panel, IAB and ZEW, Nürnberg and Mannheim, Germany (see https://www.gruendungspanel.de/en/zew-start- up-panel/home, accessed on 7 April 2025). The data are not publicly available but can be accessed upon request from the data providers. No new data were generated for this study.

Conflicts of Interest: The author declares no conflict of interest.

5.6 Appendix

TABLE 5-7. Descriptive statistics (a) and variance inflation factor (VIF) (b).

(a)

Descriptive Statistics	**Mean**	**St. Dev.**	**Min**	**Max**
Firm size (employees) (mean)	0	1	−0.68	15.785
Firm size (turnover) (mean)	0	1	−0.051	19.698
In-house R&D (mean)	0	1	−0.614	7.354
Manufacturing industries (mode)	0.697	0.46	0	1
Firm age (mean)	0	1	−2.969	4.658
Creative class	0	1	−0.987	6.347
Amenities	0	1	−1.551	3.303
Population-employment density	0	1	−0.682	6.288
Population growth	0	1	−3.278	3.385
Public transportation	0	1	−0.758	11.036
Cycle lanes	0	1	−0.146	14.488
Entrepreneurial ecosystems (EEs) (PCA)	0	1	−7.035	1.451
Region type	1.703	0.835	1	3

(b)

Descriptive Statistics	**VIF**
Firm size (employees) (mean)	1.058

Firm size (turnover) (mean)	1.016
In-house R&D (mean)	1.107
Manufacturing industries (mode)	1.064
Firm age (mean)	1.111
Creative class	1.682
Amenities	3.002
Population-employment density	2.224
Population growth	1.195
Public transportation	1.708
Cycle lanes	1.039
Entrepreneurial ecosystems (EEs) (PCA)	1.481

5.7 References

1. Fishman, E. Bikeshare: A review of recent literature. Transp. Rev. 2016, 36, 92–113. [CrossRef]

2. Pucher, J.; Buehler, R. Walking and cycling for healthy cities. Built Environ. 2010, 36, 391–414. [CrossRef]

3. Audretsch, D.B.; Heger, D.; Veith, T. Infrastructure and entrepreneurship. Small Bus. Econ. 2015, 44, 219–230. [CrossRef]

4. Audretsch, D.B.; Belitski, M. Entrepreneurial ecosystems in cities: Establishing the framework conditions. J. Technol. Transf. 2017,

42, 1030–1051. [CrossRef]

5. Stam, E.; Spigel, B. Entrepreneurial Ecosystems; USE Discussion Paper Series; Utrecht University: Utrecht, The Netherlands, 2016.

6. Audretsch, D.B.; Belitski, M. Towards an entrepreneurial ecosystem typology for regional economic development: The role of creative class and entrepreneurship. Reg. Stud. 2021, 55, 735–756. [CrossRef]

7. Hechavarría, D.M.; Ingram, A.E. Entrepreneurial ecosystem conditions and gendered national-level entrepreneurial activity: A 14-year panel study of GEM. Small Bus. Econ. 2019, 53, 431–458. [CrossRef]

8. Miles, M.P.; Morrison, M. An effectual leadership perspective for developing rural entrepreneurial ecosystems. Small Bus. Econ.

2020, 54, 933–949. [CrossRef]

9. Leendertse, J.; Schrijvers, M.; Stam, E. Measure twice, cut once: Entrepreneurial ecosystem metrics. Res. Policy 2022, 51, 104336. [CrossRef]

10. Schaltegger, S.; Wagner, M. Sustainable entrepreneurship and sustainability innovation: Categories and interactions. Bus. Strategy Environ. 2011, 20, 222–237. [CrossRef]

11. Volkmann, C.; Fichter, K.; Klofsten, M.; Audretsch, D.B. Sustainable entrepreneurial ecosystems: An emerging field of research.

Small Bus. Econ. 2021, 56, 1047–1055. [CrossRef]

12. Pankov, S.; Velamuri, V.K.; Schneckenberg, D. Towards sustainable entrepreneurial ecosystems: Examining the effect of contextual factors on sustainable entrepreneurial activities in the sharing economy. Small Bus. Econ. 2021, 56, 1073–1095. [CrossRef]

13. DiVito, L.; Ingen-Housz, Z. From individual sustainability orientations to collective sustainability innovation and sustainable entrepreneurial ecosystems. Small Bus. Econ. 2021, 56, 1057–1072. [CrossRef]

14. Bischoff, K. A study on the perceived strength of sustainable entrepreneurial ecosystems on the dimensions of stakeholder theory and culture. Small Bus. Econ. 2021, 56, 1121–1140. [CrossRef]

15. Wagner, M.; Schaltegger, S.; Hansen, E.G.; Fichter, K. University-linked programmes for sustainable entrepreneurship and regional development: How and with what impact? Small Bus. Econ. 2021, 56, 1141–1158. [CrossRef]

16. Wurth, B.; Stam, E.; Spigel, B. Toward an entrepreneurial ecosystem research program. Entrep. Theory Pract. 2022, 46, 729–778. [CrossRef]

17. IAB/ZEW Start-up Panel, IAB and ZEW, Nürnberg and Mannheim, Germany. 2021. Available online: https://www. gruendungspanel.de/en/zew-start-up-panel/home (accessed on 20 October 2022).

18. Rosário, A.T.; Raimundo, R.J.; Cruz, S.P. Sustainable entrepreneurship: A literature review. Sustainability 2022, 14, 5556. [CrossRef]

19. Muñoz, P.; Cohen, B. Sustainable entrepreneurship research: Taking stock and looking ahead. Bus. Strategy Environ. 2018, 27, 300–322. [CrossRef]

20. Bergset, L.; Fichter, K. Green start-ups—A new typology for sustainable entrepreneurship and innovation research. J. Innov. Manag. 2015, 3, 118–144. [CrossRef]

21. Schumpeter, J.A. The Theory of Economic Development; Harvard University Press: Cambridge, MA, USA, 1934.

22. Parrish, B.D. Sustainability-driven entrepreneurship: Principles of organization design. J. Bus. Ventur. 2010, 25, 510–523. [CrossRef]

23. Kuckertz, A.; Wagner, M. The influence of sustainability orientation on entrepreneurial intentions—Investigating the role of business experience. J. Bus. Ventur. 2010, 25, 524–539. [CrossRef]

24. Patzelt, H.; Shepherd, D.A. Recognizing opportunities for sustainable development. Entrep. Theory Pract. 2011, 35, 631–652. [CrossRef]

25. Welter, F. Contextualizing entrepreneurship—Conceptual challenges and ways forward. Entrep. Theory Pract. 2011, 35, 165–184. [CrossRef]

26. Stam, E.; Welter, F. Geographical contexts of entrepreneurship: Spaces, places and entrepreneurial agency. In The Psychology of Entrepreneurship; Routledge: London, UK, 2020; pp. 263–281.

27. Stam, E.; Van de Ven, A. Entrepreneurial ecosystem elements. Small Bus. Econ. 2021, 56, 809–832. [CrossRef]

28. Bischoff, K.; Volkmann, C.K. Stakeholder support for sustainable entrepreneurship—A framework of sustainable entrepreneurial ecosystems. Int. J. Entrep. Ventur. 2018, 10, 172–201. [CrossRef]

29. Fichter, K.; Fuad-Luke, A.; Hjelm, O.; Klofsten, M.; Backman, M.; Bergset, L.; Bienkowska, D.; Clausen, J.; Geier, J.; Hirscher, A.L.; et al. SHIFTing the Support of Entrepreneurship in Eco-Innovation. SHIFT Project Summary; SHIFT: Helsinki, Finland, 2016.

30. O'Shea, G.; Farny, S.; Hakala, H. The buzz before business: A design science study of a sustainable entrepreneurial ecosystem.

Small Bus. Econ. 2021, 56, 1097–1120. [CrossRef]

31. Woolley, J.L. The creation and configuration of infrastructure for entrepreneurship in emerging domains of activity. Entrep. Theory Pract. 2014, 38, 721–747. [CrossRef]

32. Hickman, R.; Banister, D. Transport and the environment. In A Research Agenda for Transport Policy; Edward Elgar Publishing: Cheltenham, UK, 2019; pp. 25–33.

33. Fishman, E. Cycling as transport. Transp. Rev. 2016, 36, 1–8. [CrossRef]

34. Pucher, J.; Buehler, R. Cycling towards a more sustainable transport future. Transp. Rev. 2017, 37, 689–694. [CrossRef]

35. Stucki, T. Success of start-up firms: The role of financial constraints. Ind. Corp. Chang. 2014, 23, 25–64. [CrossRef]

36. Volker, J.M.B.; Handy, S. Economic impacts on local businesses of investments in bicycle and pedestrian infrastructure: A review of the evidence. Transp. Rev. 2021, 41, 401–431. [CrossRef]

37. Speckemeier, L.; Tsivrikos, D. Green entrepreneurship: Should legislators invest in the formation of sustainable hubs? Sustainability

2022, 14, 7152. [CrossRef]

38. Tiba, S.; van Rijnsoever, F.J.; Hekkert, M.P. Sustainability startups and where to find them: Investigating the share of sustainability startups across entrepreneurial ecosystems and the causal drivers of differences. J. Clean. Prod. 2021, 306, 127054. [CrossRef]

39. Hudde, A. Educational differences in cycling: Evidence from German cities. Sociology 2022, 56, 909–929. [CrossRef]

40. Pugh, R.; MacKenzie, N.G.; Jones-Evans, D. From 'techniums' to 'emptiums': The failure of a flagship innovation policy in Wales.

Reg. Stud. 2018, 52, 1009–1020. [CrossRef]

41. Lepoutre, J.; Justo, R.; Terjesen, S.; Bosma, N. Designing a global standardized methodology for measuring social entrepreneurship activity: The Global Entrepreneurship Monitor social entrepreneurship study. Small Bus. Econ. 2013, 40, 693–714. [CrossRef]

42. European Cyclists' Federation. ECF Tracker 2.0. 2024. Available online: https://www.ecf.com/en/resources/ecfs-cycling- infrastructure-tracker/ (accessed on 12 September 2023).

43. Ton, D.; Duives, D.C.; Cats, O.; Hoogendoorn-Lanser, S.; Hoogendoorn, S.P. Cycling or walking? Determinants of mode choice in the Netherlands. Transp. Res. Part A Policy Pract. 2019, 123, 7–23. [CrossRef]

44. Pucher, J.; Buehler, R. Integrating bicycling and public transport in North America. J. Public Transp. 2009, 12, 79–104. [CrossRef]

45. Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR). Raumgliederungen des BBSR. 2021. Available online: https://www.bbsr.bund.de/BBSR/DE/forschung/raumbeobachtung/Raumabgrenzungen/raumabgrenzungen-uebersicht.html (accessed on 9 September 2021).

46. Mouratidis, K. Urban planning and quality of life: A review of pathways linking the built environment to subjective well-being. Cities 2021, 115, 103229. [CrossRef]

47. Jacobs, J. The Death and Life of Great American Cities; Random House: New York, NY, USA, 1961.

48. Greenacre, M.; Groenen, P.J.F.; Hastie, T.; d'Enza, A.I.; Markos, A.; Tuzhilina, E. Principal component analysis. Nat. Rev. Methods Primers 2022, 2, 100. [CrossRef]

49. European Commission. Regional Competitiveness Index 2.0—2022 Edition. European Union, n.d. 2022. Available online: https://ec.europa.eu/regional_policy/information-sources/maps/regional-competitiveness_en (accessed on 7 April 2024).

50. Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR). Indikatoren und Karten zur Raum- und Stadtentwicklung. INKAR. 2021. Available online: https://www.inkar.de/ (accessed on 17 November 2021).

51. Riandita, A.; Broström, A.; Cagliano, R. Partnering with green start-ups: A vehicle for eco-innovation? Ind. Innov. 2025, 32, 24–52. [CrossRef]

52. Hörisch, J.; Kollat, J.; Brieger, S.A. Environmental orientation among nascent and established entrepreneurs: An empirical analysis of differences and their causes. Int. J. Entrep. Ventur. 2019, 11, 373–393. [CrossRef]

53. Hájek, P.; Stejskal, J. R&D cooperation and knowledge spillover effects for sustainable business innovation in the chemical industry. Sustainability 2018, 10, 1064. [CrossRef]

54. Delgado-Gomes, V.; Oliveira-Lima, J.A.; Martins, J.F. Energy consumption awareness in manufacturing and production systems.

Int. J. Comput. Integr. Manuf. 2017, 30, 84–95. [CrossRef]

55. Mayer, H.; Habersetzer, A.; Meili, R. Rural–urban linkages and sustainable regional development: The role of entrepreneurs in linking peripheries and centers. Sustainability 2016, 8, 745. [CrossRef]

56. Lopes, J.M.; Silva, L.F.; Massano-Cardoso, I.; Galhardo, A. Green Purchase Determinants in a Rural Region of Europe: How can green marketing influence consumers' decisions? The mediating role of green awareness of price. Adm. Sci. 2024, 14, 293. [CrossRef]

57. Theodoraki, C. Building entrepreneurial ecosystems sustainably. Found. Trends Entrep. 2024, 20, 384–480. [CrossRef]

58. Hull, A.; O'Holleran, C. Bicycle Infrastructure: Can Good Design Encourage Cycling? Urban Plan. Transp. Res. 2014, 2, 369–406. [CrossRef]

59. Helferich, M.; Tröger, J.; Dütschke, E. The role of automobility engagement for car use and car use reduction intentions in Germany. Transp. Res. Part F Traffic Psychol. Behav. 2024, 106, 199–214. [CrossRef]

6 Discussion and Conclusion

This dissertation analyzed how regional entrepreneurial ecosystems (EEs) contribute to (1) product innovation in start-ups, on the one hand, and (2) facilitate green start-up activity, on the other hand. While differing in focus, they represent complementary avenues through which start-ups can drive both competitiveness and ecological sustainability in advanced economies. Accordingly, this dissertation explores how regional EEs can serve as enabling environments to support innovation-led and ecologically sustainable entrepreneurial outcomes. In doing so, Germany offered a particularly relevant context due to the juxtaposition of its advanced economy with a globally comparatively underperforming and regionally uneven start-up landscape (Sternberg et al., 2024). Through a regional lens, this research seeks to inform more nuanced, place-based policy strategies aimed at leveraging regional EEs to promote synergistic development goals.

The scientific contribution of this dissertation is threefold. First, the first paper fills a critical gap in the EE literature by examining the mechanisms through which ecosystem-level components influence product innovation outcomes in start-ups, with particular attention paid to the differences between urban and rural regions (*Chapter 3*). By shifting the traditional firm-centric focus (see e.g., Beugelsdijk, 2007; Naz et al., 2015; Niebuhr et al., 2020; Sternberg & Arndt, 2001) towards broader regional dynamics, this research also contributes to the regional innovation literature by emphasizing how place-based factors influence innovation outcomes. Second, the second paper responds to the limited understanding of how EEs support sustainability-oriented ventures such as green start-ups (Volkmann et al., 2021). By exploring the role of EEs in facilitating green start-up activity (*Chapter 4*), this research contributes to both the EE and SEE literature by offering novel insights into how traditional ecosystems can support sustainability-oriented ventures and by identifying the specific conditions that require adaptation to foster green start-up activity. Third, the scientific contribution of the third paper lies in exploring alternative metrics to better facilitate green start-up activity in traditional EEs through the example of cycling infrastructure (*Chapter 5*). Moving beyond the traditional emphasis on carbon-intensive transportation modes (see e.g., Audretsch et al., 2021; Leendertse et al., 2022), it empirically establishes the importance of cycling infrastructure as a key factor supporting green start-up activity. This novel insight advances both the EE and SEE literature by highlighting a new, infrastructure-oriented pathway for embedding ecological sustainability into ecosystem design and policy. Furthermore, by demonstrating the influence of cycling infrastructure on start-up activity, this research also contributes to the broader entrepreneurship debate as one of the first empirical studies to examine this relationship.

In the following *Section 6.1*, the empirical findings of the papers are discussed in relation to one another: Are there any patterns, contrasts, or evolving insights across these studies? Hereinafter, the theoretical implications of the findings are represented (*Section 6.2*), outlining the consequences for research in the field of EEs, SEEs, and the regional innovation and entrepreneurship literature more broadly. This is followed by practical implications for policymaking in *Section 6.3*. Lastly, this chapter discusses the limitations of the dissertation and suggestions for future research in *Section 6.4*.

6.1 Empirical findings and linkages between the papers

The first paper (*Chapter 3*) has demonstrated that the influence of ecosystem-level components on product innovation in start-ups differs[12] across urban and rural regions. For example, in rural regions, financial capital is positively associated with radical product innovations, with no observed significant effect in urban regions. As rural regions are often characterized by so-called "peripheral innovation systems," external resources like financial capital can play a critical compensatory role in overcoming resource constraints to innovate (Tödtling & Trippl, 2005). These findings highlight the need for a so-called *place-sensitive ecosystem design* (see Figure 6-1). This entails that urban and rural regions require different ecosystem-level components, for example, knowledge, finance, and networks, to shape product innovation outcomes in start-ups.

[12] Both in terms of effect size through average marginal effects (AMEs) and statistical significance.

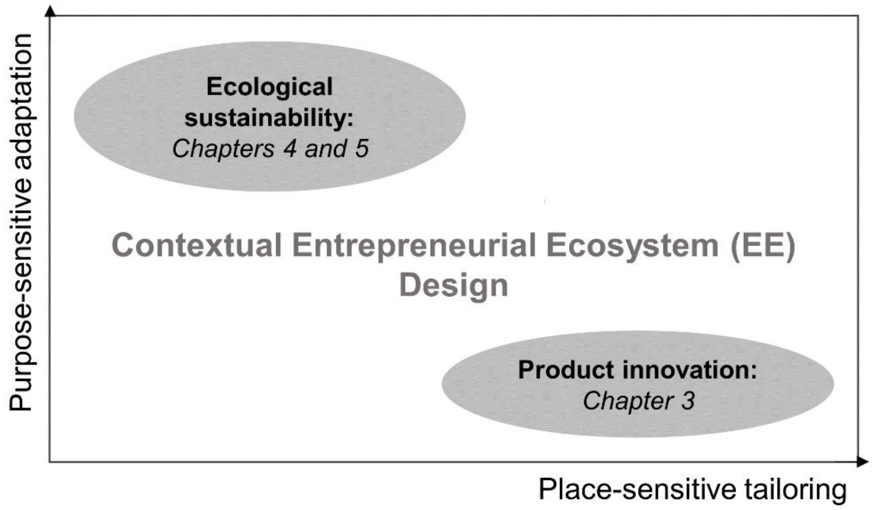

FIGURE 6-1. Contextual entrepreneurial ecosystem (EE) design.

In contrast, the second paper (*Chapter 4*) has shown that many ecosystem-level components are not necessarily unsuitable across different types of regions, as in the first paper (*Chapter 3*), but rather misaligned with the purpose of green entrepreneurship. While potential differences in effect strength across region types were not modelled directly in the multilevel (hierarchical) model, the second paper's findings reflect average patterns across urban, intermediate, and rural regions. Taken together, these patterns indicate a partial misalignment between EEs and the unique needs of green start-ups at the regional level in Germany. These misalignments are particularly evident with the ecosystem-level components of formal institutions and innovation networks, which are often oriented toward conventional business models that emphasize economic growth over (ecological) sustainability (Asheim & Coenen, 2005). However, culture, intermediary services, and regional market demand (GDP per capita) in traditional EEs still show significant and positive associations with green start-up activity. Although with the latter, it remains unclear whether growth-oriented indicators such as GDP per capita, as a representative of market demand, truly facilitate ecological sustainability transitions or merely enable marginal green business models within existing unsustainable paradigms (Braun & Schulz, 2021). Furthermore, the significant interaction effects, for example, between physical infrastructure and market demand, show that isolated components are insufficient to address; systemic approaches are necessary to support ecological sustainability transitions. Related to the first paper (*Chapter 3*), this raises a question for future research as to how interdependencies between ecosystem-level components might also shape product innovation outcomes. Overall, the second paper (*Chapter 4*) reflects a thematic mismatch between traditional EEs and the mission-driven character of green start-ups in certain ways. As opposed to the first paper (*Chapter 3*), these findings highlight the need for so-called *purpose-sensitive adaptation* in EEs (see Figure 6-1), where adaptation of certain ecosystem-level components is necessary to break free from systemic lock-ins that inhibit green start-up activity.

This brings us to the third paper (*Chapter 5*), which complements and reinforces the *purpose-sensitive adaptation* logic of the second paper (*Chapter 4*) in Figure 6-1. Building on the premise that traditional EEs do not adequately support green start-up activity in certain ways, Chapter 5 extends the dissertation by exploring alternative, purpose-aligned ecosystem metrics. Through the example of cycling infrastructure, it analyzes how physical infrastructure in traditional EEs can be reoriented to better accommodate green start-ups. The third paper's findings reveal a strong and statistically significant positive association between the share of cycling infrastructure and green start-up activity at the regional level in Germany. This relationship reflects average patterns across urban, intermediate, and rural regions through a multilevel (hierarchical) model, thereby strengthening the robustness of the findings. By demonstrating that targeted, sustainability-oriented infrastructure can play a meaningful role in supporting green entrepreneurship, the third paper (*Chapter 5*) offers practical insights into how EEs can evolve to be more inclusive of ecologically sustainable-driven entrepreneurship. However, the significant relationship between cycling infrastructure and green start-up activity is not amplified by the wider EE, indicating a potential disconnect between cycling infrastructure and traditional EEs, with the latter prioritizing economic growth over sustainability (Theodoraki et al., 2022). Even when physical infrastructure aligns with green start-up goals – in this case, cycling infrastructure – its impact remains fragmented if not embedded within a more holistic, ecological sustainability-oriented ecosystem. According to the theory underpinning EEs, infrastructure interventions alone cannot drive meaningful entrepreneurial change unless integrated into the broader EE's institutional arrangements, and resources such as knowledge and networks (Wurth et al., 2022). This suggests that piecemeal improvements are insufficient to facilitate green start-up activity at a systemic level. This reinforces the argument that supporting green start-up activity requires not just isolated adjustments, but a comprehensive, *purpose-sensitive adaptation* of traditional EEs (see Figure 6-1).

In other words, while the second paper (*Chapter 4*) and third paper (*Chapter 5*) highlight the need to reconfigure EEs to overcome systemic lock-ins that inhibit green start-up activity, the first paper (*Chapter 3*) points to a similar imperative from a spatial perspective. It shows that the impact of certain ecosystem-level components on product innovation outcomes in start-ups varies significantly between urban and rural regions, emphasizing that EEs must be adapted to local conditions rather than applied uniformly. Together, the three papers build a broader imperative that EEs must be tailored or reconfigured rather than treated as "one-size-fits-all," whether to fit different regional contexts (*Chapter 3*) or to align with green entrepreneurship (*Chapters 4 & 5*) in Figure 6-1.

6.2 Theoretical implications

The first paper (*Chapter 3*) challenges the dominance of firm-level perspectives in innovation research (see e.g., Beugelsdijk, 2007; Naz et al., 2015; Niebuhr et al., 2020; Sternberg & Arndt, 2001). The findings demonstrate that the regional context remains a significant explanatory factor in how product innovation in start-ups unfolds. As such, this study highlights the importance of incorporating regional heterogeneity into theoretical frameworks that seek to explain firm-level innovation. Neglecting such heterogeneity risks producing an overly simplified and potentially misleading account of the drivers of product innovation in practice. With this being said, the findings challenge the dominant assumption in much of the innovation literature that regional influences are uniform across space. For example, Bellmann et al. (2018) have examined product innovation in firms at the regional level but rely on data aggregated across all regions, thereby obscuring critical inter-regional differences and potentially masking context-specific mechanisms. This research, by contrast, demonstrates that regional heterogeneity is not merely a statistical nuisance but a theoretically meaningful dimension that shapes how innovation processes operate. It therefore challenges overly generalized models and underscores the need for theoretical frameworks that incorporate spatial contingency. In particular, it invites a rethinking of canonical innovation models to account for place-based characteristics that condition innovation outcomes, especially in early-stage firms like start-ups, where innovation activity is more tied to and shaped by the local environment (Sternberg, 2007). Beyond its implications for the regional innovation literature, this chapter also contributes to the literature on EEs. EEs are often portrayed as engines of innovation (see e.g., Brown & Mason, 2017; Feld, 2020; Feldman et al., 2019; Spigel, 2017), with the implicit or explicit assumption that this role holds across different kinds of regions. However, the findings suggest that this view is overly simplistic. Rather than functioning as universally supportive environments for innovation, EEs vary in their capacity to foster productive entrepreneurship outcomes like product innovations. These findings point to the need to reconceptualize EEs not as uniform systems but as regionally contingent systems whose performance depends on context-specific characteristics, for example, institutional, cultural, and infrastructural factors.

Furthermore, this reconceptualization of EEs must also extend beyond purely growth-oriented objectives. Traditional EEs often prioritize economic growth, whereas sustainable entrepreneurship is not necessarily about growth – it is often about long-term value, environmental impact, and social inclusion. If EEs continue to only support entrepreneurship that promises rapid growth, they may exclude or undervalue sustainable ventures that grow slowly but meaningfully to society and the environment. In line with this, the second paper (*Chapter 4*) has provided empirical evidence that EEs, while not entirely capable of facilitating green start-up activity as a subset of sustainable entrepreneurship, possess embedded resources (e.g., intermediary services) and institutional settings (i.e., culture) that can be mobilized in support of green start-ups. Theoretically, this opens the door to a more integrative understanding of EEs as hybrid support structures, capable of enabling both conventional (growth-oriented) and mission-driven (sustainability-oriented) entrepreneurship. This challenges narrow theoretical interpretations of EEs as purely growth-oriented systems (see e.g., Cohen, 2006). The fact that certain ecosystem-level components facilitate green start-up activity may also signal the progressive greening of these ecosystems over time. This calls for scholars to consider the fluidity and adaptability of ecosystems, especially in response to evolving policy environments, market pressures, and cultural shifts toward sustainability. This aligns with the theory of evolutionary economic geography, suggesting that novel green entrepreneurial activities can emerge endogenously within existing systems, leading to the progressive greening of traditional EEs over time (Boschma & Frenken, 2018). It also highlights the possibility that institutional change, for example, driven by environmental norms, mission-driven entrepreneurs, or public policy, can reshape the orientation of EEs without the need for an entirely separate sub-stream on SEEs. Meanwhile, the findings challenge the prevalent dichotomy in the literature between traditional EEs and SEEs, which are often treated as mutually exclusive or separate paradigms (Volkmann et al., 2021). The second paper suggests that this binary framing may obscure important areas of overlap, interaction, and convergence because the fact that EEs, to a certain extent, are conducive to green start-up activity conceptually blurs the lines between EEs and SEEs.

However, not all components of traditional EEs are equally conducive to green start-up activity. Certain ecosystem-level components, while facilitating conventional growth, can be environmentally detrimental, raising questions about their relevance in ecosystems intended to support green ventures. This requires a critical rethinking of traditional EEs in which ways the components can better support sustainability-oriented ventures. The third paper (*Chapter 5*) has provided one example of this with a novel perspective on physical infrastructure through cycling as a pathway to facilitate green start-up activity. However, for cycling infrastructure to materialize in traditional EEs, the broader EE framework must itself evolve. The findings from the third paper indicate that traditional EEs remain structurally misaligned with forms of infrastructure more compatible with sustainability, particularly cycling infrastructure. However, as physical infrastructure is said to be a facilitator of entrepreneurship through the systemic interdependencies with other ecosystem-level components (Wurth et al., 2022), this misalignment creates friction that may undermine the support available to green start-ups in traditional ecosystems. Thus, fostering ecological sustainability in traditional EEs requires more than simply incorporating green ventures into existing systems or modifying isolated components such as physical infrastructure. Instead, this calls for a more fundamental redefinition of what constitutes a supportive ecosystem. This involves rethinking its resource endowments and institutional arrangements to ensure they reflect and reinforce sustainability-oriented ventures, rather than inadvertently reproducing the growth-driven logic of conventional ecosystems. Without such systemic reorientation, support for green entrepreneurship risks being superficial, fragmented, or constrained by underlying structures that remain incompatible with ecological sustainability. This reorientation also speaks to emerging debates on degrowth and post-growth theories, which imply that growth for its own sake is increasingly incompatible with both environmental and societal progress (Affolderbach & Schulz, 2024; Schulz & Bailey, 2014). As such, this research invites a critical rethinking of EEs through a degrowth or post-growth lens. Rather than assuming that all growth-enhancing elements of EEs are universally supportive of different kinds of sustainability-oriented ventures, it becomes necessary to ask: Growth of what, for whom, and at what cost?

6.3 Policy implications

The geographical location continues to shape the product innovation potential of start-ups, though in uneven ways. The regional context – particularly the urban–rural divide – plays a critical role in determining the effectiveness of various product innovation drivers. Therefore, tailored policy approaches are required to support product innovations in start-ups across different regional settings. In urban regions, policies should continue to prioritize and strengthen R&D investment. The significant and positive association between intramural R&D expenditures and incremental product innovations suggests that urban start-ups benefit significantly from a strong knowledge base. While the creative and cultural industries (CCIs) also contribute to incremental product innovation, their impact is comparatively lower in urban than in rural regions. As such, support for these sectors should be complementary to core R&D policies in urban regions. In contrast, rural regions require a different set of policy instruments. Here, R&D expenditures alone are insufficient to stimulate product innovation due to the relative absence of dense knowledge networks. Instead, rural innovation policy should leverage the disproportionately strong influence of the CCIs on incremental product innovations. For example, public investment in local cultural programs, targeted training programs, as well as residency programs for creative professionals, and the development of local creative clusters can be beneficial to stimulate product innovation outcomes in rural-based start-ups. Moreover, radical product innovations in rural regions are significantly enhanced by financial support mechanisms. This finding highlights the importance of sustained, place-based funding programs designed to reduce the structural barriers rural start-ups face. Rural innovation policy should therefore include targeted grant schemes, regionally focused venture capital initiatives, and accessible public funding that explicitly supports high-risk, high-impact innovation efforts. Ensuring local awareness and administrative support for these programs will be as critical for their success. Overall, the findings highlight that EEs as product innovation drivers function differently across space. Effective innovation policy must therefore be spatially differentiated, recognizing the varying roles of knowledge, creativity, and finance in urban and rural regions. By aligning policy instruments with the specific strengths and needs of urban and rural regions, governments can more effectively enhance long-term economic competitiveness by strengthening the product innovation potential of local start-ups. While not guaranteed, this approach could simultaneously lay the groundwork for a broader transition toward (ecologically) sustainable regional economies, as innovation – even when driven by economic incentives – is needed to develop alternative business models to unsustainable practices (Kuzma et al., 2020).

Aside from the spatially differentiated need for innovation policy discussed above, there is also a need for purpose-targeted policies that account for the specific needs of green start-ups. These policies must acknowledge the limitations of a purely growth-oriented paradigm, as found in EEs, particularly in its inability, to a certain extent, to support green entrepreneurship that seeks to balance economic success with environmental impact. Nonetheless, at first, there are also enabling elements of green start-up activity within regional EEs. In particular, entrepreneurial culture and intermediary services have been shown to play a supportive role. In this context, investment in intermediary services, for example, (green) incubators and accelerators, can be particularly impactful in helping start-ups embed ecological sustainability into their core business models. However, fostering a supportive entrepreneurial culture, for example, through role models or success stories, alone is not sufficient; its impact is significantly amplified when combined with supportive physical infrastructure, a strong market demand, and intermediary services. Importantly, while physical infrastructure by itself may not drive green start-up formation, its effectiveness is greatly enhanced when there is a strong market demand for sustainable goods and services. Therefore, regional policy should aim to coordinate these elements within an integrated ecosystem approach, ensuring that cultural support and physical infrastructure are matched by resources and market opportunities. At the same time, the findings suggest that traditional ecosystem-level components, i.e., formal institutions and established innovation networks, can inadvertently hinder green start-up activity, as they often remain predominantly aligned with conventional, growth-oriented business models. To address this misalignment, policy interventions should focus on reorienting EE structures to actively support green entrepreneurship. This includes integrating environmental objectives into the operational guidelines and evaluation criteria of regional institutions, enabling them to more effectively identify and support start-ups that prioritize ecological sustainability (Hoogendoorn et al., 2019). In addition, innovation networks should be diversified to include actors such as environmental NGOs, green industries, and sustainability-focused research institutions, facilitating the formation of eco-oriented networks that better align with the specific needs of green entrepreneurship. These policy implications are particularly relevant in a broader regional context, as the findings hold across urban, intermediate, and rural regions in terms of average effects. As opposed to the need to tailor innovation policy instruments to the specific regional context, as discussed earlier, sustainability-oriented reforms to EEs should thus be implemented more broadly across all kinds of regions. By reconfiguring certain traditional ecosystem-level components, policymakers can make EEs more inclusive and responsive to the specific needs of green entrepreneurship, regardless of geographical location. A concrete example is cycling infrastructure, which has emerged in this dissertation as a critical, yet often overlooked, enabler of green start-up activity in regional EEs. Strategic investment in cycling infrastructure represents not only a relevant mobility and urban planning intervention to tackle challenges related to automobile transport planning but also a meaningful tool to facilitate green start-up activity. Together, these policy interventions can contribute to the broader transition toward ecologically sustainable regional economies through green start-up activity, which may, in turn, also lay the groundwork for long-term economic competitiveness.

6.4 Limitations and suggestions for future research

This dissertation is subject to several limitations that also open promising avenues for future research.

First, the reliance on secondary firm-level data from the IAB/ZEW Start-up Panel imposes certain constraints. Although the dataset applies standardized definitions of green start-ups, based on reductions in energy consumption and overall CO_2 emissions, these metrics remain relatively narrow. In reality, they may not fully capture the breadth, depth, or actual implementation of environmental practices within start-up ventures. Future studies could address this limitation by incorporating more nuanced data sources – for example, information on environmental certifications obtained by green ventures. This would help assess not only whether start-up ventures identify as green, but also the extent to which they generate verifiable environmental impact. Such differentiation is particularly relevant in the context of post-growth and degrowth debates, which emphasize the importance of moving beyond superficial or growth-dependent forms of (ecological) sustainability (Affolderbach & Schulz, 2024). By gaining deeper insight into how green start-ups operationalize ecological objectives, future research could better evaluate the extent of their contribution to systemic ecological sustainability transitions. This would help distinguish whether such ventures genuinely challenge unsustainable economic structures or merely reproduce green growth narratives. In addition, the secondary firm-level data does not account for the multi-dimensional nature of innovation outcomes, particularly those encompassing environmental and/or social dimensions. While economically incentivised innovation has also been significantly associated with improved sustainability performance at the firm level (Kuzma et al., 2020), future research could incorporate metrics of eco-innovation to provide a more holistic understanding of the contribution start-ups make toward ecological economic competitiveness. For example, by supplementing firm-level data with additional surveys on eco-innovation.

Second, this dissertation did not address the dynamic and evolutionary nature of EEs, mainly because of a lack of longitudinal firm-level data, for example, regarding ecological sustainability in start-up ventures. However, EEs are inherently dynamic systems that evolve over time. Future research could therefore investigate how EEs transition over time in their support towards firm-level product innovation and green entrepreneurship, and what mechanisms drive or inhibit such transformations. For example, by identifying critical junctures or path dependencies, and exploring the role of key actors such as mission-driven investors in catalyzing shifts toward ecological sustainability. Moreover, longitudinal studies could illuminate how ecosystems adapt in response to exogenous shocks (e.g., climate change) or endogenous processes (e.g., accumulation of sustainability-oriented ventures, learning effects). Such research could draw on evolutionary economic geography or transition theory to understand the conditions under which EEs move from being predominantly growth-oriented toward more inclusive and sustainability-oriented configurations. Identifying such tipping points would contribute to a more nuanced understanding of how EEs can be steered toward long-term ecological progress.

Third, a limitation of this dissertation lies in the conceptual separation between EEs and SEEs. At first glance, this distinction has been useful in clarifying the relationship between traditional ecosystems and green start-up activity to address where ecosystem-level transformation is most needed to support such ventures (Volkmann et al., 2021). However, it simultaneously risks reinforcing a binary perspective that may overlook how these systems coexist and interact in practice. In reality, EEs and SEEs are not fragmented systems; rather, they can overlap, intersect, and mutually reinforce one another in their support of sustainable entrepreneurship. Future research should move beyond segregated frameworks and investigate the dynamic interrelations between EEs and SEEs. Linking this to the dynamic nature of ecosystems, such research could also explore the pathways through which EEs might transition into SEEs. By understanding how EEs become more sustainable over time, there is also a growing need to consider who benefits from these ecosystems and who may be left behind. Not all entrepreneurs have equal access to the networks, infrastructure, and institutional support that ecosystems provide – especially because EEs are often better developed in urban than rural regions (Freire-Gibb & Nielsen, 2014). Without deliberate attention to inclusivity, ecosystems may perpetuate existing disparities by disproportionately favouring entrepreneurs with stronger social networks, financial resources, or more favourable geographical locations. A more equitable SEE would not only support environmentally beneficial ventures but also ensure that underrepresented groups – such as women, immigrants, or rural entrepreneurs – are included and empowered. Future research should explore the mechanisms through which inclusion or exclusion occurs within these evolving ecosystems and investigate how policy and ecosystem design can address barriers to participation. Doing so is essential for building ecosystems that are not only green but also just and inclusive.

Fourth, the dissertation adopted a quantitative approach that, while enabling the identification of generalizable statistical patterns, limited the exploration of alternative pathways through which EEs could evolve to more effectively support green start-up activity. Although *Chapter 5* provided an exploratory perspective on alternative metrics of EEs through the example of cycling infrastructure, there remains a need for more in-depth, qualitative research to uncover which reconfigurations in EEs are necessary to accommodate sustainability-oriented ventures. Such approaches could help identify concrete pathways for transitioning conventional EEs into more sustainability-supportive environments. In doing so, qualitative research can complement quantitative analyses by revealing the “how” and “why” behind observed patterns and helping to theorize the mechanisms that facilitate more inclusive and ecologically responsive EEs.

7 References of Chapters 1, 2, and 6

Acemoglu, D., Akcigit, U., & Celik, M. A. (2022). Radical and incremental innovation: The roles of firms, managers, and innovators. American Economic Journal: Macroeconomics, 14(3), 199-249.

Affolderbach, J., & Schulz, C. (2024). Wirtschaftsgeographien der Nachhaltigkeit. UTB.

Alvedalen, J., & Boschma, R. (2017). A critical review of entrepreneurial ecosystems research: Towards a future research agenda. European planning studies, 25(6), 887-903.

Andersson, M., & Klepper, S. (2013). Characteristics and performance of new firms and spinoffs in Sweden. Industrial and corporate change, 22(1), 245-280.

Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. Research policy, 34(8), 1173-1190.

Audretsch, D. B., & Belitski, M. (2021). Towards an entrepreneurial ecosystem typology for regional economic development: The role of creative class and entrepreneurship. Regional Studies, 55(4), 735-756.

Autio, E., Kenney, M., Mustar, P., Siegel, D., & Wright, M. (2014). Entrepreneurial innovation: The importance of context. Research policy, 43(7), 1097-1108.

Bahrami, H., & Evans, S. (1995) Flexible Re-Cycling and High-Technology Entrepreneurship. California Management Review, 37, 62-89.

Bellmann, L., Evers, K., & Hujer, R. (2018). Regional and firm-specific effects on innovations using multi-level methods. The Annals of Regional Science, 61(2), 319-349.

Bergset, L., & Fichter, K. (2015). Green start-ups–a new typology for sustainable entrepreneurship and innovation research. Journal of innovation management, 3(3), 118-144.

Beugelsdijk, S. (2007). The regional environment and a firm's innovative performance: A plea for a multilevel interactionist approach. Economic Geography, 83(2), 181–199.

Bischoff, K. (2021). A study on the perceived strength of sustainable entrepreneurial ecosystems on the dimensions of stakeholder theory and culture. Small Business Economics, 56, 1121–1140.

Boschma, R., & Frenken, K. (2018). Evolutionary economic geography. The new Oxford handbook of economic geography, 213-229.

Brown, R., & Mason, C. (2017). Looking inside the spiky bits: A critical review and conceptualization of entrepreneurial ecosystems. Small Business Economics, 49, 11–30.

Cantner, U., Cunningham, J. A., Lehmann, E. E., & Menter, M. (2021). Entrepreneurial ecosystems: a dynamic lifecycle model. Small Business Economics, 57, 407-423.

Cohen, B. (2006). Sustainable valley entrepreneurial ecosystems. Business strategy and the Environment, 15(1), 1-14.

Colombelli, A., Krafft, J., & Vivarelli, M. (2016). To be born is not enough: the key role of innovative start-ups. Small Business Economics, 47, 277-291.

Chen, X., Xie, H., & Zhou, H. (2024). Incremental versus radical innovation and sustainable competitive advantage: A moderated mediation model. Sustainability, 16(11), 4545.

Daly, H. E., & Farley, J. (2011). Ecological economics: principles and applications. Island press.

Demirel, P., Li, Q. C., Rentocchini, F., & Tamvada, J. P. (2019). Born to be green: new insights into the economics and management of green entrepreneurship. Small business economics, 52, 759-771.

DiVito, L., & Ingen-Housz, Z. (2021). From individual sustainability orientations to collective sustainability innovation and sustainable entrepreneurial ecosystems. Small Business Economics, 56(3), 1057–1072.

Doğan, E. (2016). The effect of innovation on competitiveness. Istanbul University Econometrics and Statistics e-Journal, (24), 60-81.

Dubini, P. (1989) The influence of motivations and environment on business start-ups: Some hints for public policies. Journal of Business Venturing, 4, 11-26.

Dumont, M., Rayp, G., Verschelde, M., & Merlevede, B. (2016). The contribution of start-ups and young firms to industry-level efficiency growth. Applied Economics, 48(59), 5786-5801.

Elkington, J. (1997). The triple bottom line. Environmental management: Readings and cases, 2, 49-66.

Ekins, P. (2010). Eco-innovation for environmental sustainability: concepts, progress and policies. International Economics and Economic Policy, 7, 267-290.

Feld, B. (2020). Startup communities: Building an entrepreneurial ecosystem in your city. John Wiley & Sons.

Feldman, M., Siegel, D. S., & Wright, M. (2019). New developments in innovation and entrepreneurial ecosystems. Industrial and Corporate Change, 28(4), 817–826.

Fichter, K., Olteanu, Y., Hirschfeld, A., Walk, V., Gilde, J., Grothey, T. & Neumann, T. (2024). Green Startup Monitor 2024. Berlin: Borderstep Institut, Startup Verband.

Freeman, J. H., & Audia, P. G. (2006). Community ecology and the sociology of organizations. Annu. Rev. Sociol., 32(1), 145-169.

Freire-Gibb, L. C., & Nielsen, K. (2014). Entrepreneurship within urban and rural areas: Creative people and social networks. Regional studies, 48(1), 139-153.

Freixanet, J., & Rialp, J. (2022). Disentangling the relationship between internationalization, incremental and radical innovation, and firm performance. Global Strategy Journal, 12(1), 57-81.

Fukasaku, Y. (2000). Innovation for environmental sustainability: A background. Innovation and the environment, 17-32.

Gast, J., Gundolf, K., & Cesinger, B. (2017). Doing business in a green way: A systematic review of the ecological sustainability entrepreneurship literature and future research directions. Journal of cleaner production, 147, 44-56.

Greve, H. R. (2007). Exploration and exploitation in product innovation. Industrial and corporate change, 16(5), 945-975.

Gries, T., & Naudé, W. (2009). Entrepreneurship and regional economic growth: towards a general theory of start-ups. Innovation–The European Journal of Social Science Research, 22(3), 309-328.

Hess, S., Wahl, A., & Johnson, A. R. (2025). Measuring entrepreneurial ecosystems across levels: a district approach. Small Business Economics, 1-33.

Hickman, R., & Banister, D. (2019). Transport and the environment. In A research agenda for transport policy (pp. 25-33). Edward Elgar Publishing.

Hirschfeld, A., Kollmann, T., Gilde, J., Walk, V., & Ansorge, M. (2024). Deutscher Startup Monitor 2024: Den Blick nach vorne. Bundesverband Deutsche Startups e.V.

Hoogendoorn, B., Van der Zwan, P., & Thurik, R. (2019). Sustainable entrepreneurship: The role of perceived barriers and risk. Journal of business ethics, 157, 1133-1154.

Hockerts, K., & Wüstenhagen, R. (2010). Greening Goliaths versus emerging Davids—Theorizing about the role of incumbents and new entrants in sustainable entrepreneurship. Journal of business venturing, 25(5), 481-492.

Johansson, B., & Lööf, H. (2008). Innovation activities explained by firm attributes and location. Econ. Innov. New Techn., 17(6), 533–552.

Karlsson, C., & Tavassoli, S. (2016). Innovation strategies of firms: What strategies and why?. The Journal of Technology Transfer, 41(6), 1483-1506.

Kollmann, T., & Pröpper, A. (2025). The Startup-Zoo: A Typology of Startups Based on the Ambitions of Their Founders. International Journal of Business, 14(2), 38-55.

Kuzma, E., Padilha, L. S., Sehnem, S., Julkovski, D. J., & Roman, D. J. (2020). The relationship between innovation and sustainability: A meta-analytic study. Journal of Cleaner Production, 259, 120745.

Leendertse, J., Schrijvers, M., & Stam, E. (2022). Measure twice, cut once: Entrepreneurial ecosystem metrics. Research Policy, 51(9), 104336.

Luger, M. I., & Koo, J. (2005). Defining and tracking business start-ups. Small Business Economics, 24, 17-28.

Mason, C., & Brown, R. (2014). Entrepreneurial ecosystems and growth oriented entrepreneurship. Final report to OECD, Paris, 30(1), 77-102.

Moore, J. F. (1998). The rise of a new corporate form. Washington quarterly, 21(1), 167-181.

Muñoz, P., & Cohen, B. (2018). Sustainable entrepreneurship research: Taking stock and looking ahead. Business strategy and the environment, 27(3), 300-322.

Naz, A., Niebuhr, A., & Peters, J. C. (2015). What's behind the disparities in firm innovation rates across regions? Evidence on composition and context effects. The Annals of Regional Science, 55, 131–156.

Niebuhr, A., Peters, J. C., & Schmidke, A. (2020). Spatial sorting of innovative firms and heterogeneous effects of agglomeration on innovation in Germany. The Journal of Technology Transfer, 45(5), 1343–1375.

Nijkamp, P. (2003). Entrepreneurship in a modern network economy. Regional studies, 37(4), 395-405.

OECD. (2005). Oslo Manual: Guidelines for collecting and interpreting innovation data (3rd ed.). OECD Publishing. https://doi.org/10.1787/9789264013100-en.

Pennings, J. M. (1982) The urban quality of life and entrepreneurship. Academy of Management Journal 25(1): 63-79.

Reguia, C. (2014). Product innovation and the competitive advantage. European Scientific Journal, 1(1), 140-157.

Riandita, A., Broström, A., & Cagliano, R. (2025). Partnering with green start-ups: a vehicle for eco-innovation?. Industry and Innovation, 32(1), 24-52.

Rocha, H., & Audretsch, D. B. (2022). Entrepreneurial ecosystems, regional clusters, and industrial districts: Historical transformations or rhetorical devices?. The Journal of Technology Transfer, 1-24.

Roundy, P. T., & Lyons, T. S. (2023). Where are the entrepreneurs? A call to theorize the micro-foundations and strategic organization of entrepreneurial ecosystems. Strategic Organization, 21(2), 447-459.

Schaltegger, S., Beckmann, M., & Hockerts, K. (2018). Collaborative entrepreneurship for sustainability. Creating solutions in light of the UN sustainable development goals. International Journal of Entrepreneurial Venturing, 10(2), 131-152.

Schaltegger, S., & Wagner, M. (2011). Sustainable entrepreneurship and sustainability innovation: categories and interactions. Business strategy and the environment, 20(4), 222-237.

Schaper, M. (2016). Understanding the green entrepreneur. In Making ecopreneurs (pp. 7-20). Routledge.

Schautschick, P., & Greenhalgh, C. (2016). Empirical studies of trade marks–the existing economic literature. Economics of innovation and new technology, 25(4), 358-390.

Schulz, C., & Bailey, I. (2014). The green economy and post-growth regimes: opportunities and challenges for economic geography. Geografiska Annaler: Series B, Human Geography, 96(3), 277-291.

Schulz, C., & Braun, B. (2021). Post-growth perspectives in Economic Geography. DIE ERDE–Journal of the Geographical Society of Berlin, 152(4), 213-217.

Schumpeter, J.A. (1934) The Theory of Economic Development, Cambridge, ma: Harvard University Press.

Shepherd, D. A., & Patzelt, H. (2011). The new field of sustainable entrepreneurship: Studying entrepreneurial action linking "what is to be sustained" with "what is to be developed". Entrepreneurship theory and practice, 35(1), 137-163.

Spigel, B. (2017). The relational organization of entrepreneurial ecosystems. Entrepreneurship theory and practice, 41(1), 49-72.

Spigel, B., Kitagawa, F., & Mason, C. (2020). A manifesto for researching entrepreneurial ecosystems. Local Economy, 35(5), 482-495.

Spigel, B., & Stam, E. (2018). Entrepreneurial ecosystems. In SAGE handbook of entrepreneurship and small business (p. 21). Sage.

Stam, E. (2015). Entrepreneurial ecosystems and regional policy: a sympathetic critique. European planning studies, 23(9), 1759-1769.

Stam, E., & Spigel, B. (2016). Entrepreneurial ecosystems (Vol. 16, No. 13, pp. 1-15). USE Discussion paper series.

Stam, E., & Welter, F. (2020). Geographical contexts of entrepreneurship: Spaces, places and entrepreneurial agency. In The psychology of entrepreneurship (pp. 263-281). Routledge.

Stam, E., & Van de Ven, A. (2021). Entrepreneurial ecosystem elements. Small business economics, 56(2), 809-832.

Sternberg, R. (2007). Entrepreneurship, proximity and regional innovation systems. Tijdschrift voor economische en sociale geografie, 98(5), 652-666.

Sternberg, R., & Arndt, O. (2001). The firm or the region: What determines the innovation behavior of European firms? Economic Geography, 77(4), 364–382.

Sternberg, R., Gorynia-Pfeffer, N., Täube, F., Wendt, N., Baharian, A., & Wallisch, M. (2024). GEM Deutschland 2023/2024 nationaler Bericht. Global Entrepreneurship Monitor.

Steyaert, C., & Katz, J. (2004). Reclaiming the space of entrepreneurship in society: geographical, discursive and social dimensions. Entrepreneurship & regional development, 16(3), 179-196.

Tacq, J. (2011). Causality in qualitative and quantitative research. Quality & Quantity, 45(2), 263-291.

Tamásy, C. (2006). Determinants of regional entrepreneurship dynamics in contemporary Germany: A conceptual and empirical analysis. Regional studies, 40(4), 365-384.

Theodoraki, C., Dana, L. P., & Caputo, A. (2022). Building sustainable entrepreneurial ecosystems: A holistic approach. Journal of Business Research, 140, 346-360.

Tödtling, F., & Trippl, M. (2005). One size fits all?: Towards a differentiated regional innovation policy approach. Research policy, 34(8), 1203-1219.

Tukker, A., & Jansen, B. (2006). Environmental impacts of products: A detailed review of studies. Journal of Industrial Ecology, 10(3), 159-182.

Van de Ven, A. (1993) The Development of an Infrastructure for Entrepreneurship. Journal of Business Venturing, 8: 211-230.

Volkmann, C., Fichter, K., Klofsten, M., & Audretsch, D. B. (2021). Sustainable entrepreneurial ecosystems: An emerging field of research. Small Business Economics, 56(3), 1047-1055.

Welter, F. (2011). Contextualizing entrepreneurship—conceptual challenges and ways forward. Entrepreneurship theory and Practice, 35(1), 165-184.

Wurth, B., Stam, E., & Spigel, B. (2022). Toward an entrepreneurial ecosystem research program. Entrepreneurship Theory and Practice, 46(3), 729-778.

Zahra, S. A. (2007). Contextualizing theory building in entrepreneurship research. Journal of Business venturing, 22(3), 443-452.

Zahra, S. A., Wright, M., & Abdelgawad, S. G. (2014). Contextualization and the advancement of entrepreneurship research. International small business journal, 32(5), 479-500.

Zimmermann, V. (2025). KfW SME innovation report 2024: Economic activity puts the brakes on innovation activity. KfW Research.

Start-ups are increasingly seen as key drivers of both innovation for competitiveness and ecological transformation in advanced economies. However, the regional conditions that support these dual goals remain largely unexplored. This dissertation investigates how regional entrepreneurial ecosystems (EEs) in Germany shape two forms of start-up activity: those engaging in product innovation, on the one hand, and green business activities, on the other.

Drawing on regional econometric analyses, this research highlights the importance of tailoring EEs to both the local context and the specific needs of start-ups. While traditional EEs can contribute to product innovation in start-ups, depending on the regional context, they often fall short in supporting green start-ups due to structural mismatches. By examining alternative, purpose-aligned ecosystem indicators through the example of cycling infrastructure, this research also demonstrates how reconceptualized ecosystem-level components can better align with ecological sustainability.

The findings advance EE theory and provide practical guidance for regional policymakers seeking to design more inclusive, innovation-friendly, and ecologically sustainable regional start-up environments.

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