Ecosystems of green entrepreneurship in perspective: evidence from Brazil

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Abstract: While our comprehension on the configurations and dynamics of entrepreneurial ecosystems has advanced significantly, there remains a conspicuous gap in how localised phenomena shape transitions towards environmentally sustainable regions – particularly outside the scope of advanced nations. Accordingly, our research explores how entrepreneurial ecosystems affect the emergence of green entrepreneurship within a developing country context. The empirical setting comprises data from the State of São Paulo, Brazil for the period 2002–2019. Econometric estimations involved generalised estimating equations for count data in a panel dataset. Results highlight that entrepreneurial ecosystems for green entrepreneurship appear to strongly rely on research universities, innovation habitats and connections to global value chains. These findings contribute to policymaking processes looking to further connect the promotion of knowledge-intensive entrepreneurship with environmentally sustainable transitions within entrepreneurial ecosystems.

Keywords: knowledge-intensive entrepreneurship; KIE; green entrepreneurship; ecosystems of entrepreneurship; entrepreneurial ecosystems; bioeconomy; bio-based entrepreneurship; developing countries; Brazil; panel data; negative binomial estimations; generalised estimating equations.

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1 Introduction

Knowledge-intensive entrepreneurship (KIE) is a concept that comprehends small, innovation-oriented firms that demonstrate pervasive positive effects in contexts in which they are embedded (Malerba and McKelvey, 2020). These companies demonstrate intense interdependence with other elements of the socio-economic scene (Radosevic and Yoruk, 2013). Growing attention to entrepreneurial ecosystems (EEs) has been paid by academics and practitioners over the last decade, allowing a better understanding of how the connections involving individual and contextual features help shaping entrepreneurial events (Audretsch and Belitski, 2017; Stam and Spigel, 2016). Typical conceptualisations of EEs comprehend aspects associated with the presence and interaction among dimensions (or components) that include human capital, universities, support systems (such as incubators and science parks), local market conditions, connections with the global economy, infrastructure, availability of financial assets, and entrepreneurial culture (Alves et al., 2021; Mason and Brown, 2014; Stam and Spigel, 2016).

Such components and their respective interactions seem to have a local character in shaping conditions for KIE, comprising neighbouring conditions associated with knowledge generation and diffusion, institutional conditions, resource availability and market dynamics (Isaksen and Trippl, 2017). Ultimately, these conditions generate a concentrated geography of KIE activity as observed for the case of both developed and developing economies (Pan and Yang, 2019; Fischer et al., 2018).

Notwithstanding, KIE dynamics can present high levels of heterogeneity when it comes to different sectors and areas of activity (Malerba and McKelvey, 2020). Thus, more refined assessments concerning the variety of entrepreneurial endeavours that fall under this conceptual landmark are due. Within the broader context of KIE, green entrepreneurship – a concept that involves the orientation of entrepreneurs towards environment-friendly business activities – has gained prominence as a vector of sustainable change in economics systems (O'Neill and Gibbs, 2016; Shepherd and Patzelt, 2011; Pacheco et al., 2010; Hall et al., 2010). Intertwined with United Nations' Sustainable Development Goals (SDGs), green entrepreneurship can fill voids not covered by incumbents and promote desirable – and necessary – structural shifts (Horne et al., 2020; Parrish, 2010). These features are enhanced when green entrepreneurship becomes knowledge-intensive, considering their enhanced capacity of launching innovative products, processes and services (Horbach, 2020).

Yet, while our comprehension on the configurations and dynamics of EEs has advanced significantly (Audretsch et al., 2020; Kuckertz, 2019), there remains a conspicuous gap in our knowledge on how localised phenomena shape transitions towards environmentally sustainable economic structures and regions, particularly outside the scope of developed nations (Raposo et al., 2021; Potluri and Phani, 2020; Demirel et al., 2019; Hansen and Coenen, 2015). This is critical in a moment in which countries and regions face difficulties in fostering ecosystems dedicated to address green practices (OECD, 2019). Hence, our research concentrates on exploring how EEs affect the emergence of green entrepreneurship within a developing country context. Our exploratory assessment is based on the following research questions: Is 'green' KIE affected by typical EE dimensions? Or are there configurational specificities driving the emergence of this particular cohort of KIE? By delving into these inquiries our assessment contributes to literature by offering a comparative view on the underlying ecosystem dynamics taking place within the scope of green entrepreneurship.

Our empirical setting comprises data from the State of São Paulo, Brazil, a leading economic region with 44 million inhabitants and which responds for roughly a third of the Brazilian GDP. We gather data for KIE activity from the PIPE Program, a SBIR-like policy managed by the São Paulo Research Foundation. Besides overall KIE and green KIE data, we have looked into sub-specifications of green entrepreneurship associated with applications to smart city concepts and bio-based green entrepreneurship (a typical manifestation of the bioeconomy). City and microregion-level data across the entire state were used to appraise the impacts of ecosystems components on different manifestations of KIE. Main findings highlight the localised nature of EEs in all cases – since city-level determinants were more consistent than results observed for microregions. While similarities emerge, EEs for green entrepreneurship appear to rely more on innovation habitats (incubators and tech parks) and connections to global value chains than what has been observed for overall KIE. Also, ecosystems seem to be at a lower stage of maturity concerning the intersection of green entrepreneurship oriented to smart city applications. These findings contribute to policymaking processes looking to further connect the promotion of KIE with environmentally sustainable transitions.

After this introductory section, the remaining of the article is structured as follows: Section 2 explores key concepts and elements associated with KIE, EE dynamics and the green entrepreneurial event. Section 3 presents our methodological approach. Section 4 outlines the empirical findings which are then discussed in Section 5. Section 6 concludes with final remarks, implications and limitations of our assessment.

2 Literature review

KIE is a phenomenon attached to innovation capabilities derived from scientific and technological assets available in small companies in diverse sectors (Malerba and McKelvey, 2020). These ventures are responsible for the "creation, diffusion, and use of knowledge; introduce new products and technologies; draw resources and ideas from their innovation system; and introduce change and dynamism into the economy" [Malerba and McKelvey, (2020), p.503]. For these reasons, KIE has become a socio-economic event that receives increasing levels of attention from academics and policymakers (Audretsch et al., 2020; Kantis et al., 2020). But while KIE requires individual behaviour and skills, its emergence is largely shaped by the context in which agents are embedded, a feature that has been frequently addressed as ecosystems of entrepreneurship (EE) (Alves et al., 2021).

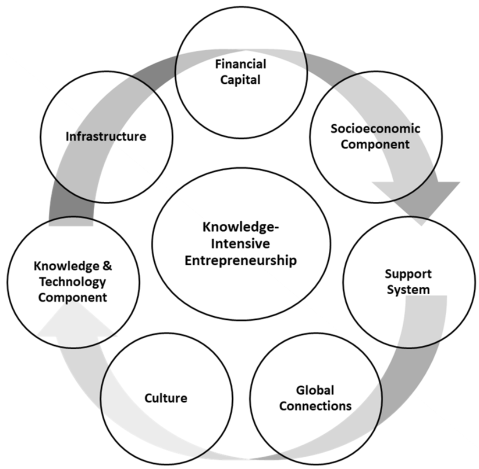
2.1 Ecosystems of entrepreneurship

The underlying rationale of EE is based on a biological metaphor that underscores the critical importance of interactions among myriad agents in defining an environment conducive to the entrepreneurial event (Kuckertz, 2019; Belitski and Godley, 2020). Mason and Brown (2014, p.5) offer a widely used definition for this analytical concept: "a set of interconnected entrepreneurial actors, entrepreneurial organisations, institutions and entrepreneurial processes which formally and informally coalesce to connect, mediate and govern the performance within the local entrepreneurial environment." Another key feature in this regard concerns the spatial nature of EE, i.e., they are meta-structures ingrained in geographical regions (Martinidis et al., 2021; Malecki, 2018; Ács et al., 2017). As a result, physical distance negatively affects knowledge flows, thus highlighting how the immediate context can have pervasive impacts on KIE activity (Strumsky and Thill, 2013; Crescenzi and Rodríguez-Pose, 2012).

Typical components of EE involve universities as agents of knowledge generation and diffusion (Heaton et al., 2019; Malecki, 2018; Carayannis et al., 2016); incubators and tech parks, considering their influence in offering a relevant infrastructure for connecting entrepreneurs with other firms, universities and society (Zou and Zhao, 2014); human capital, an item that enhances innovative potential in individuals (Martinidis et al., 2021; Chatterji et al., 2013); technological activity, a core source of spillovers for KIE

(Radosevic and Yoruk, 2013); density of knowledge flows and networks, a key vector in transmitting intangible skills and assets (Tsouri and Pegoretti, 2020); agglomeration economies (Balland et al., 2018); funding availability (Pan and Yang, 2019); local market dynamics and connections to global value chains (Lee et al., 2020); infrastructural conditions (Audretsch and Belitski, 2017); and entrepreneurial culture (Qian, 2018). A summary of these elements is presented in Figure 1, where underlying arrows identify interactions among EE dimensions.

Figure 1 EE dimensions



Source: Authors based on referenced literature

2.2 A 'green' perspective on EE

Since the release of the Brundtland report in 1987, eco-innovations and sustainability-oriented innovations – approaches to innovative activity that address ecological and social aspects in products, processes, services and business models – became a trending topic in academia, practice and policy (Klewitz and Hansen, 2014; Kuckertz and Wagner, 2010). Even though concepts related to sustainable development are often ambiguous and controversial, they have become increasingly significant in the domain of entrepreneurship studies, considering the potential entrepreneurs have in defining new technological trajectories (Hall et al., 2010). Usual definitions encompass innovative entrepreneurial endeavours tackling pressing environmental demands through the identification and exploration of business opportunities that minimise ventures' impacts on the natural environment (Gast et al., 2017; Hockerts and Wüstenhagen, 2010; York and Venkataraman, 2010). This leads to a somewhat distinct entrepreneurial rationale in which the creation of environmental value becomes a key driver in individual-level behaviour (Hanohov and Baldacchino, 2018; Lotfi et al., 2018). Because of its orientation towards addressing new opportunities – often reliant on the development of new technologies and/or innovative business models – green entrepreneurial activity can be perceived as a specific type of KIE.

Alongside these analytical aspects, a key complement to the broad definition of green entrepreneurship has been related to the incorporation of bio-based production strategies in new ventures, an approach that has been termed as bioeconomy. Such concepts comprehend the use and conservation of renewable biological sources – bioenergy, bioproducts, biofuels – with the goal of generating a more environmentally sustainable society (Raimondo et al., 2018; Mason et al., 2012). Again, knowledge intensity is a key feature of these entrepreneurial ventures. Scientific and technological discoveries, often at the frontier of knowledge, play a key role in the emergence and competitiveness of bio-based companies (Kuckertz et al., 2020).

Still, even though these breeds of entrepreneurship have taken a centre stage in academic and policymaking debates, our knowledge concerning their interrelationships with ecosystem features, components and interactions remains largely uncharted by dedicated literature (Demirel et al., 2019). Recent assessments have looked into the link between EEs and sustainable transitions from a national-level perspective, offering limited insights to understand how these aspects are intertwined from a local standpoint (Raposo et al., 2021). While the basic EE seems to apply (Kuckertz et al., 2020; Kuckertz, 2020), some specific findings in literature also highlight differential features. First, although the spatial dynamics of green and bio-based entrepreneurship are also highly localised and place-dependent (Hansen and Coenen, 2015), the frequently needed access to renewable biological resources exerts influence in the geographical distribution of these firms (Philp and Winickoff, 2017).

Second, since green entrepreneurial endeavours can contribute with new technologies and solutions for urban areas, these ventures can assist ecosystems in connecting the location itself to sustainable transitions from a bottom-up approach (Mullins, 2017). A recent trend in this respect concerns entrepreneurs' contributions to the implementation of green smart-city tools in urban environments, such as green buildings, resource-saving transportation networks, smart grids, artificial intelligence applied to water management and other connectivity features that reduce environmental impacts (Martin et al., 2019; Nielsen, 2016). Recent research has found that smart cities present several opportunities for sustainable entrepreneurial endeavours (Barba-Sánchez et al., 2019). Entrepreneurs often tap into favourable circumstances posed by smart cities in terms of complementary assets and resources (Winters, 2011), thus contributing to strengthen environment-friendly initiatives (Bifulco et al., 2016). In this regard, the emergence of green KIE oriented towards smart city technologies can likely help shaping the nature of the entire ecosystems in which it is located.

Third, markets for green and bio-based products and services are often untried and value attribution from customers can be problematic (OECD, 2019). In turn, this reflects in higher levels of market uncertainty and in the existence of additional barriers for access to capital and investments – even in relatively mature ecosystems (Potluri and Phani, 2020). Such circumstances require increased attention from policy initiatives to develop awareness and conditions for these industries to flourish (Haldar, 2019). In this context, science and technology parks and business incubators can be key in nurturing the development and evolution of these entrepreneurial ventures in a protected habitat (Zeng et al., 2021; Cohen, 2006).

On the other hand, green enterprises – particularly those from emerging economies – might have facilitated access to international markets (Potluri and Phani, 2020) and open up collaboration opportunities with foreign players (Philp and Winickoff, 2017). As a result, green and bio-based entrepreneurship can reap substantial benefits from ecosystem-level connections to global value chains.

Additionally, green and bio-based entrepreneurs face an imperative need to tap into critical knowledge, assets and skills available in the region in order to overcome their limitations in terms of resources (Horbach, 2020). This situation is maximised considering the increasingly technological complexity and interdisciplinary approaches required to launch eco-innovations (Demirel et al., 2019). For this reason, intense cooperation among entrepreneurial ventures, universities and the overall technological environment represent a pivotal element in ecosystems of green entrepreneurship (Kuckertz, 2020; Demirel et al., 2019). Universities have also helped shaping the conditions for environmentally sustainable entrepreneurship by adding dedicated programs to foster this mindset in students and faculty (Wagner et al., 2021; Hall et al., 2010). Although such conditions have also been observed for the case of overall KIE activity (Fischer et al., 2018), green entrepreneurship depends more substantially on scientific developments arising from academia (Rosenlund and Legrand, 2021; Angelova and Pastarmadzhieva, 2020).

3 Methodological approach

Our methodological take on the dynamics of green EEs is based on the estimation of entrepreneurial propensity functions dealing with effects associated with ecosystem-level predictors on the generation of entrepreneurial events. The research setting comprehends information for all cities and microregions[1] in the State of São Paulo, Brazil, with available data (629 and 43 geographical units, respectively). This procedure allows establishing a more consistent view on EEs by investigating statistical associations from a multi-scalar standpoint. Since there is no agreement in literature concerning the spatial reach of EEs (Malecki, 2018; Qian et al., 2012), the identification of differential relationships among variables of interest according to distinct boundary definitions is likely to render more insightful results for policymakers (Kuckertz, 2019; Roundy et al., 2018).

The State of São Paulo offers an interesting case of analysis to understand the dynamics of green KIE within the context of developing countries. While this region stands as the leading economy in Brazil, it still faces myriad challenges that are typical manifestations of catching-up economies, including severe institutional voids, pronounced agglomeration diseconomies due to infrastructural issues and a feeble business environment for innovation-driven entrepreneurship (Fischer et al., 2018). Notwithstanding, the state government – through its research foundation – has created an initiative that resembles the Small Business Innovation Research (SBIR) Program in the USA to nurture the emergence of KIE: the PIPE Program. PIPE offers subsidies for entrepreneurial projects with high levels of knowledge-intensity and innovative potential in small ventures located in the State of São Paulo. Last, this specific region comprises the bulk (roughly 80%) of start-ups in sectors related to green entrepreneurship in Brazil (Dias et al., 2019). Combined, these features create a relevant context to address the dynamics of EE in a peripheral economy.

Table 1 Analytical variables

Ecosystem dimension	*Variable*	*Description*	*Source*
Entrepreneurial events (dependent)	KIE	Sum of entrepreneurial projects' grants (PIPE/FAPESP) assigned to a city/micro-region in each analytical period.	São Paulo Research Foundation
	Green KIE	Subcohort of KIE involving projects dedicated to *addressing environmental challenges*.	São Paulo Research Foundation
	Smart city and green KIE	Subcohort of green KIE involving projects dedicated to addressing environmental challenges *through approaches connected to smart city concepts*.	São Paulo Research Foundation
	Bio-based KIE	Subcohort of KIE involving *bio-based projects*.	São Paulo Research Foundation
Knowledge and technology component (independent)	Research university	Presence of at least one high-quality research university campus in the city/micro-region in each analytical period. Binary variable.	Scimago Institutional Ranking
	Tertiary enrolment	Average share of city/micro-region population enrolled in higher education institutions in each analytical period.	São Paulo Statistical Foundation
	Patents per capita	Average number of patent deposits per capita registered at the Brazilian Institute of Industrial Property in the city/micro-region in each analytical period.	Brazilian Institute of Industrial Property
Interactions component (independent)	Technology transfer	Average number of technology licensing agreements per capita registered at the Brazilian Institute of Industrial Property in the city/micro-region in each analytical period.	Brazilian Institute of Industrial Property
	U-I interactions	Sum of reported university-industry interactions in the city/micro-region in each analytical period.	Brazilian Research Council – Directory of Research Groups

Notes: Each analytical period covers three consecutive years. Dependent variables are lagged in one period, comprehending data for 2005–2019. Correspondingly, predictors represent data for 2002–2016. The panel dataset includes data for 5 periods in 629 cities and 43 micro-regions.

Table 1 Analytical variables (continued)

Ecosystem dimension	*Variable*	*Description*	*Source*
Culture (independent)	SME share	Average share of companies with less than 100 employees in the city/micro-region in each analytical period.	Brazilian Ministry of Economics
Global connections (independent)	Export-import activity	Average share of companies involved with export and/or import activity in the city/micro-region in each analytical period.	Brazilian Ministry of Economics
	FDI	Occurrence of at least one foreign direct investment event in the city/micro-region in each analytical period.	São Paulo Statistical Foundation
Support system (independent)	Incubators and tech parks	Presence of at least one incubator or tech park in the city/micro-region in each analytical period. Binary variable.	São Paulo Investment Agency
Socio-economic component (Independent)	GDP per capita	Average GDP per capita in the city/micro-region in each analytical period. Values in 2019 Brazilian reais.	São Paulo Statistical Foundation
	Population	Average population in the city/micro-region in each analytical period.	São Paulo Statistical Foundation
	Population density	Average rate of inhabitants per square kilometre in the city/micro-region in each analytical period.	São Paulo Statistical Foundation
Financial capital (independent)	Credit availability	Average values of credit operations per capita in the city/micro-region in each analytical period. Values in 2019 Brazilian reais.	São Paulo Statistical Foundation
Infrastructure (independent)	Energy consumption	Average consumption of electric energy (MWh) per capita in the city/micro-region in each analytical period.	São Paulo Statistical Foundation
Core-periphery component (independent)	Distance to main economic hub	Road distance from each municipality to the main economic hub, the city of São Paulo. For microregions, the distance is given by average distances for each group of municipalities.	Google Maps

Notes: Each analytical period covers three consecutive years. Dependent variables are lagged in one period, comprehending data for 2005–2019. Correspondingly, predictors represent data for 2002–2016. The panel dataset includes data for 5 periods in 629 cities and 43 micro-regions.

In order to reduce effects from yearly variations in analytical variables, our dataset has been developed using three-year periods. This has required the calculation of variables' sum (for count data), averages (for continuous data) or maximum values (for binary indicators). Details are presented in Table 1 (summary statistics can be found in Appendix). Our research timeframe covers data from 2002 until 2019 (six periods). The construction of the dataset took into account that the causal path between contextual features and the emergence of entrepreneurial ventures should not be taken as simultaneous. Hence, our models draw from the notion that ecosystem-level components will affect entrepreneurial behaviour with a lag. Although there is no consistent recommendation in literature as per a proper temporal connection in this case, following a similar approach to that in Qian et al. (2012), we assume that a one-period lag is reasonable. Accordingly, our yearly timeframe covers information for the period 2002–2016 for independent variables and 2005–2019 for dependent variables. This procedure reduced our total coverage to five analytical periods.

3.1 Dependent variables

Our set of dependent variables is derived from information related to the PIPE program (innovative research in small enterprises) managed by the São Paulo Research Foundation (Fapesp). This dataset comprises public information on approved projects obtained from Fapesp's institutional website. Although this dataset potentially represents a fraction of the KIE scenario in the area being studied, it offers a consistent source of KIE for the Brazilian context (Alves et al., 2021; Fischer et al., 2018).

For each project, besides data about the company itself (and its location), information is provided for the knowledge field, keywords, and the description of the proposal – including its content and expected direct and indirect impacts. Based on this information, we ran content analysis for all 1,372 firms included in the PIPE dataset. Following the lag procedure described, this comprehends projects granted in the 2005–2019 period. Content analysis was performed independently by two of the authors. These results were then combined to classify projects according to their alignment with green entrepreneurship concepts. Discrepancies were settled by the other two authors. We have derived three categories associated to green entrepreneurship in order to have a comprehensive perspective of this phenomenon based on entrepreneurial projects with different orientations.

The *green KIE* categorisation took into account projects involving explicit goals related to products, processes, services or business models encompassing environment-friendly and sustainable entrepreneurial opportunities (following Ye et al., 2020; Lotfi et al., 2018). A total of 343 projects (25% of total KIE projects) was identified. Second, we address *green KIE applied to the concept of smart cities*, that is, initiatives targeted at urban modernisation policy. This specific group involves entrepreneurial ventures based on connections of multiple city elements to improve the provision of services and urban planning with positive environmental impacts (De Jong et al., 2015; Lee et al., 2014). 81 projects (a subcohort of *green entrepreneurship*) fell in this category (6% of total KIE projects). Since smart cities are intertwined with the very dynamics of EEs, this category adds relevant insights to our empirical approach. Because of specificities related to bioeconomy dynamics, we also generated a *bio-based KIE* category, another subcohort of *green KIE* dealing with "the production of renewable biological resources and the conservation of these resources and waste streams into value added products, such as food, feed, biobased products and bioenergy" [European Commission, (2021), p.9]. 235 knowledge-intensive entrepreneurial projects were classified in this category (17.13% of total KIE projects).

Last, with the objective of having a benchmark, total *KIE* projects (1,372) were also taken as a dependent variable. This allows a more nuanced perspective on the extent to which dimensions of EEs in the State of São Paulo affect the emergence of environment-friendly KIE activity respective to the overall dynamics observed for knowledge-intensive entrepreneurial projects in general.

3.2 Independent variables

The set of independent variables used in our sample comprehends nine dimensions that allow offering a rather detailed view of entrepreneurship determinants associated with the ecosystem rationale. A first dimension gathers information concerning *knowledge and technology components* that encompass three indicators. First, research universities are included considering their pervasive effects in the dynamics of knowledge generation and deployment within ecosystems of innovation and entrepreneurship (Guerrero et al., 2016; Schaeffer et al., 2018). Our inclusion criteria in this case were based on the selection of eminent research universities located in the State of São Paulo (based on the Scimago institutional ranking). We cross-checked results with data from the São Paulo Research Foundation Grants and Scholarships database. All selected locations/year corresponded to the group of leading cities/microregions in terms of research funding, warranting robustness to our selection. In turn, tertiary enrolment allows observing impacts of educational attainment in the population in general, a measure of human capital (Fischer et al., 2018). Third, Patents are applied as a representation of the intensity of technological activity at the local/regional level (Kuckertz, 2019), an aspect that has been associated with new venture formation in developing country contexts (Tran and Santarelli, 2017).

Second, we looked into *interaction components*, considering its central position in the dynamics of EEs (Mason and Brown, 2014). Interactions are measured through formal relationships attached to technology transfer practices and linkages between academia and industry. Although limited, formal interactions offer more consistent indicators to be assessed over time and across distinct geographical units (Rondé and Hussler, 2005). Because university-industry connections are fundamentally associated with research universities, this variable entered our estimations as a moderator of research universities (multiplicative interaction term). Entrepreneurial *culture* (Fritsch et al., 2019) is approximated by the prevalence of small business in each location. *Global connections*, an ecosystem dimension that represents the extent to which local markets are involved with global value chains (Lee et al., 2020), is approached with measures considering the share of firms involved with export-import activities and the occurrence of inward foreign direct investments.

Support systems is included as a dimension representing the provision of incubators and/or tech parks, taken as dedicated habitats to nurture innovation-driven activity in connection to KIE (Alves et al., 2021; Giner et al., 2016). The *socio-economic component* gathers information on three different drivers. First, per capita income levels offer a reasonable proxy for demand quality and productivity levels (Radosevic and Yoruk, 2013). Second, total population allows controlling for the aggregate pool of potential entrepreneurs in each location (Fischer et al., 2018). Third, population density offers information on the dynamics of agglomeration economies/diseconomies. For the case of developing countries, urban areas with large concentrations of people are often associated with negative impacts on innovative activity due to typical maladies observed in places that face severe institutional voids (Glaeser and Xiong, 2017).

Capital availability for entrepreneurs is yet another dimension included in our analysis (Alves et al., 2021). *Infrastructure* conditions are approximated by levels of energy consumption per capita, as connections to the electrical grid offer a reliable proxy for overall infrastructure (Agénor, 2015). Last, the *core-periphery component* analyses the distance of locations to the main economic hub in the region: the city of São Paulo. This is a key feature in the geography of EEs considering that proximity to urban agglomerations is likely to enhance ecosystems' connections to larger markets and denser business networks (Crescenzi and Rodríguez-Pose, 2012).

3.3 Estimation procedures

Our empirical assessment is based on an entrepreneurial production function following a similar structure to that of Fischer et al. (2018) for overall KIE emergence:

$$E_{it} = f\left(KT_{it-1}, IC_{it-1}, C_{it-1}, GC_{it-1}, SS_{it-1}, SC_{it-1}, FC_{it-1}, INF_{it-1}, CPC_{it-1}, \varepsilon\right) \quad (1)$$

where E refers to our entrepreneurial events in city/microregion i in period t. These events are then set as a function of EEs' components in the same city/microregion i in period $t - 1$. These elements comprehend the dimensions presented in Table 1, that is: knowledge and technology component (*KT*), interactions component (*IC*), culture (*C*), global connections (*GC*), support system (*SS*), socio-economic component (*SC*), financial capital (*FC*), infrastructure (*INF*), and the core-periphery component (*CPC*). ε introduces the error term to the simplified model.

The estimation strategy involves the application of generalised estimating equations (population average model) for panel data with count outcomes. Negative binomial models were used due to overdispersion in the distribution of all dependent variables. Valid samples for city-level analysis comprehend 3,145 observations (city/period) and 215 observations for microregions (microregion/year). Z-scores were calculated in order to harmonise resulting coefficients due to heterogeneous scales in continuous and count independent variables. Eight models in total were estimated to address the four specifications of KIE for both geographical levels of analysis.

4 Empirical analysis

The first step in our empirical appraisal deals with a characterisation of the different definitions of KIE included in our analysis. As mentioned, the total amount of KIE projects serves as a benchmark for comparison concerning green and bio-based entrepreneurial endeavours. Table 2 brings a brief depiction of KIE decomposition for each subcohort addressed and Figure 2 outlines the spatial distribution of projects across the State of São Paulo, Brazil. Green KIE represents one quarter of the total KIE ventures in the sample, while bio-based KIE comprehends roughly one sixth of the analysed population. In turn, the connection between green entrepreneurship and applications for smart city initiatives stands for a much more marginal phenomenon. In all cases, geographical concentration stands out with particular emphasis on the top-five locations which are indicated in Figure 2.

Table 2 Characterisation of KIE distribution in the State of São Paulo, Brazil

	KIE		*Green KIE*	
	Cities	*Micro-regions*	*Cities*	*Micro-regions*
Total projects	1,372	343	81	235
% of total KIE	-	25%	5.90%	17.12%
Spatial Gini coefficient	0.96	0.84	0.97	0.83
% top-5 locations	68.44%	82.36%	66.18%	78.13%
	Smart city and green KIE		*Bio-based KIE*	
	Cities	*Micro-regions*	*Cities*	*Micro-regions*
Total projects				
% of total KIE				
Spatial Gini coefficient	0.99	0.88	0.97	0.82
% top-5 locations	82.71%	86.41%	61.70%	77.87%

Figure 2 Geographical distribution of KIE projects

Notes: Heatmap ranging from light grey (smallest numbers) to black (largest numbers). Five leading cities in absolute terms for each KIE group are outlined. Only cities with the occurrence of KIE projects are delineated in each map.

Source: The authors (based on data from the PIPE Program/São Paulo Research Foundation)

A noteworthy aspect of projects' decomposition in the maps is the inclusion of Piracicaba as a leading ecosystem for green and bio-based entrepreneurship. While this city does not rank among the top locations in terms of total KIE, its conditions in terms of offering a nurturing ecosystem for AgTechs is likely to justify its position when it comes to environment-friendly entrepreneurial initiatives. The other five cities included in this ranking (São Paulo, Campinas, São José dos Campos, São Carlos and Ribeirão Preto) form a well-known technological corridor spanning across roughly 400 kilometres with high-quality road connections (Alves et al., 2021; Fischer et al., 2018). The city of São Paulo, the state's capital and leading axis of South America's largest metropolitan area, comprehends the majority of projects in all instances, highlighting its dominant role in the region in terms of KIE activity in its different definitions.

Table 3 City-level estimations

	Model			
	KIE	*Green KIE*	*Smart city and green KIE*	*Bio-based KIE*
Research university	1.876*** [0.221]	1.444*** [0.286]	2.112*** [0.790]	1.881*** [0.320]
Tertiary enrolment	0.343*** [0.053]	0.447*** [0.063]	–0.005 [0.242]	0.407*** [0.073]
Patents	0.126*** [0.044]	0.052 [0.098]	0.078 [0.208]	0.134** [0.067]
Technology transfer	0.130*** [0.044]	0.084 [0.063]	0.109 [0.115]	0.036 [0.075]
Research university* U-I interactions	0.173*** [0.041]	0.164*** [0.045]	0.207*** [0.067]	0.129*** [0.047]
SME share	0.202* [0.122]	0.435*** [0.215]	0.851 [0.609]	0.636** [0.272]
Export-import activity	0.328*** [0.084]	0.382*** [0.122]	0.496 [0.310]	0.379** [0.152]
FDI	0.262 [0.165]	0.428* [0.251]	0.168 [0.513]	0.568** [0.278]
Incubators and tech parks	0.636*** [0.248]	1.036*** [0.308]	2.463*** [0.761]	0.193 [0.356]
GDP per capita	0.113** [0.045]	0.147** [0.066]	0.284** [0.130]	0.201*** [0.066]
Population	0.010 [0.045]	–0.004 [0.046]	–0.076 [0.071]	0.040 [0.053]
Population density	–0.074 [0.061]	–0.146 [0.089]	0.001 [0.192]	–0.185 [0.126]
Credit availability	–0.981 [0.694]	–0.623 [1.007]	–0.626 [1.949]	–0.112 [0.555]
Energy consumption	–0.010 [0.056]	–0.034 [0.126]	–0.038 [0.345]	0.082 [0.051]
Distance to main economic hub	–0.488*** [0.122]	–0.579*** [0.167]	–0.217 [0.371]	–0.255 [0.174]
Valid N	3,145	3,145	3,145	3,145
Wald chi sq.	603.39	483.09***	195.50***	306.98***

Notes: Std. errors in brackets; *sig. at 10%; **sig. at 5%; ***sig. at 1%.

Following this initial assessment on the spatial dynamics of KIE location, our analytical exercise dedicates attention to understanding the ecosystem dynamics across the State of São Paulo, allowing to compare discrepancies in terms of key enablers concerning KIE *in general* and the relevant drivers for green ventures (and its subcohorts). Tables 3 (city-level) and 4 (microregion-level) address these features. A first aspect that stands out is the fundamentally local nature of EEs in the sample, particularly so for models involving green and bio-based entrepreneurship. This interpretation of estimations comes from the more complete set of significant predictors in estimations for the city-level, as well as for the direct comparison of magnitude in coefficients. A first element that deserves attention is the role played by research universities. Except for the case of the green KIE model for microregions, these institutions appear to be pivotal elements in structuring ecosystems. But even in this case, when the presence of a leading research university is moderated by levels of university-industry interactions, its coefficient becomes significant and positive. In fact, for all estimations, the inclusion of the moderator has an increasing effect on academic contributions to the ecosystem, underscoring the importance of academic connections to markets in order to approximate these agents and promote entrepreneurial activity. Substantial differences between 'typical' and green EEs could not be observed in this case.

This is also mostly the case for tertiary enrolment as a representation of human capital. In this case, the variable is not constrained by the research quality of academic institutions, but it provides a complementary view on how educational levels can provide a qualified pool of individuals for entrepreneurial endeavours. However, for this particular variable, impacts are strongly localised, and positive effects are solely identified for city-level analyses. Interestingly, its effects are stronger for green and bio-based KIE than for total KIE, but its coefficient is not significant for the intersection between green KIE and smart city applications. For the case of micro-regions, this variable becomes negative and significant for total KIE and smart city and green KIE models, a puzzling finding that is presumably associated with the geographically bounded impacts arising from this indicator. Patents (as an indicator of inventive capabilities) also has its contributions to the generation of entrepreneurial events restricted to the level of cities. But in this case, this vector of the knowledge and technology component of ecosystems lacks predictive power for green entrepreneurship – although it has a similar effect for both total KIE and bio-based KIE.

The intensity of technology transfer is yet another ecosystem feature that is locally ingrained at the level of cities. But this is only the case for total KIE, signalling some level of immaturity in terms of interactions when considering EEs in the context of green entrepreneurship. For the microregion-level, this indicator even appears as negatively associated with smart city and green KIE and bio-based KIE. In turn, taking the share of SMEs as a representation of entrepreneurial culture, green and bio-based KIE appear to receive stronger impacts than overall KIE at the level of cities, but the significance attached to this variable in the microregion-level is only associated with overall KIE.

As per the global connections dimension, FDI activity has positive effects on green and bio-based KIE, a feature that distinguishes these dynamics from those observed for total KIE activity. The share of exporting/importing firms in the population of companies has a larger weight as predictor for all cases (even at the microregion-level, when it is actually increased), but its repercussions are consistently greater for green and bio-based entrepreneurship. Taken together, these outcomes suggest that knowledge-intensive ventures in fields dealing with environmental sustainability writ large or operating in the bioeconomy context shall benefit more from ecosystems' linkages with global value chains than the average KIE firm.

For the case of support infrastructures such as incubators and tech parks, its impacts could not be observed only for bio-based KIE. On the other hand, substantial effects appear to be present specifically for green KIE oriented at smart city applications – and the effects for overall green KIE are also substantially stronger than those detected for total KIE. These support organisations can thus be highlighted as critical components for environment-friendly KIE.

Table 4 Microregion-level estimations

	Model			
	KIE	*Green KIE*	*Smart city and green KIE*	*Bio-based KIE*
Research university	1.450*** [0.387]	0.893 [0.585]	2.062** [1.050]	1.066* [0.575]
Tertiary enrolment	–0.370** [0.183]	0.055 [0.229]	–1.446*** [0.560]	–0.065 [0.239]
Patents	0.108 [0.115]	0.117 [0.154]	0.016 [0.322]	0.229 [0.158]
Technology transfer	0.099 [0.126]	0.009 [0.158]	–0.563** [0.267]	–0.346* [0.188]
Research university* U-I interactions	0.846*** [0.201]	0.549** [0.222]	1.335*** [0.305]	0.714*** [0.228]
SME share	0.390* [0.202]	0.263 [0.294]	1.057 [0.662]	0.353 [0.306]
Export-import activity	0.744** [0.307]	1.233** [0.483]	2.068** [0.808]	1.174** [0.486]
FDI	–0.065 [0.244]	–0.021 [0.329]	0.584 [0.741]	–0.143 [0.367]
Incubators and tech parks	0.570* [0.321]	0.888** [0.429]	3.674*** [0.901]	0.356 [0.418]
GDP per capita	0.234** [0.111]	0.124 [0.161]	0.709* [0.381]	0.503*** [0.160]
Population	1.528* [0.811]	3.809** [1.834]	2.591 [3.259]	4.632** [2.075]
Population density	–1.562* [0.884]	–4.409** [2.096]	–3.468 [3.691]	–4.944*** [2.337]
Credit availability	–0.565*** [0.199]	–0.169 [0.232]	–0.412 [0.411]	–0.536* [0.254]
Energy consumption	0.006 [0.135]	–0.143 [0.166]	–0.056 [0.208]	0.049 [0.157]
Distance to main economic hub	–292 [0.253]	–0.456 [0.355]	–0.888* [0.492]	–0.120 [0.332]
Valid N	215	215	215	215
Wald chi sq.	123.69***	85.23***	86.05***	81.76***

Notes: Std. errors in brackets; *sig. at 10%; **sig. at 5%; ***sig. at 1%.

Observations for socio-economic components of EEs comprehend the expected positive role of income per capita at the city- and microregion-level for most models. Population – as a control for city/microregion size – is only significant when considering larger areas, but effects associated with large urban areas are more than compensated by negative effects of population density. This situation can be attributed to issues related to agglomeration diseconomies that are often present in large cities located in developing countries (Fischer et al., 2018). Our specification of credit availability did not render any significant and positive results – its coefficients are only significant for micro-regions but with negative signs [a structural issue associated with lack of funding for green entrepreneurship that has also been observed in Potluri and Phani (2020)]. Energy consumption as a proxy for infrastructural quality also performs poorly as an EE predictor in all cases. Proximity to the main economic hub (the city of São Paulo) is relevant for total KIE and green KIE, but spatial dispersion does not seem to affect bio-based KIE in any case, suggesting the existence of more decentralised ecosystems in this particular context. For green KIE associated to smart city applications, city-level distances to the main economic hub are not significant, but negative effects at the micro-region level indicate the presence of benefits arising from proximity to the leading regional market.

5 Discussion

Our research has addressed the dynamics and key drivers behind the emergence of knowledge-intensive *green* entrepreneurship within the context of a developing country. We have also established direct comparisons with the observed features of *overall* KIE activity. By delving into these elements, we have offered novel evidence on specificities of the green entrepreneurship phenomenon from the perspective of EEs, thus contributing to this uncharted topic (Demirel et al., 2019). We have also looked into distinct geographical scopes (cities and microregions), allowing a thorough examination of the spatial reach of ecosystem dimensions. In addition, our detailed analysis of green entrepreneurship applied to smart city concepts, as well as bio-based KIE, provide a robust picture of our research object.

First, general results demonstrate more consistent patterns in associations among predictors and dependent variables at the level of cities. This is in accordance with previous assessments that highlighted the greater relevance of these spatial units as the effective *loci* of EE (Florida et al., 2016; Cruz and Teixeira, 2014; Arauzo-Carod, 2008) and eco-innovative companies (Coll-Martinez et al., 2020). Because the EE rationale draws essentially from knowledge spillovers, increased distances can hinder the occurrence of necessary knowledge flows to take place and promote entrepreneurial events (Ács et al., 2009). In order to increase the spatial reach of local-level ecosystems, interregional connectivity should be optimised to foster integration (Balland and Boschma, 2021). Of course, the spatial reach of functional regions and their respective knowledge networks can vary, so further insights on the geography of entrepreneurship in a given area are needed to guide robust policy frameworks (Ascani et al., 2020; Carayannis et al., 2018).

Second, findings have underscored the coexistence of similarities and differences concerning how individual components shape entrepreneurial events. First, research universities appear as pivotal agents in moulding ecosystem conditions for KIE emergence. These associations become weaker and blurrier for the level of microregions, indicating that knowledge flows from these institutions are localised in space. Although these conditions are in line with prior literature (e.g., Wagner et al., 2021; Fischer et al., 2018), we have failed to notice clear differences for overall KIE and our specifications of green entrepreneurship, thus contrasting with observations from Rosenlund and Legrand (2021). More geographically concentrated patterns could be identified for human capital (approximated by tertiary enrolment), in which all positive effects are circumscribed to cities. Moreover, we have advanced on this line of reasoning by addressing the extent to which academia is connected to markets, a typical conduit for entrepreneurial activity to develop (Schaeffer et al., 2018). Contributions arising from academia were significantly enhanced in this case – and more so at the microregion-level. Particularly, smart city-oriented applications of green entrepreneurship were maximised. Taking these findings into account, stronger linkages between universities and businesses can likely be a key to nurture KIE activity – and *environment-friendly* KIE – in EEs.

Third, some compelling differences emerge when we compare green to total KIE. The observed dynamics for technology transfer processes indicate a lower relative level of maturity in EE concerning how these flows affect green entrepreneurship. For the case of Patents (as a representation of technological activity), only the bio-based subcohort of green entrepreneurship is positively affected [in line with Kuckertz et al. (2020)]. Hence, the processes through which technology is generated and transferred seem to reach substandard conditions for green entrepreneurship in our sample. These market inefficiencies may require further evolution of EEs to allow denser networks to rise – an aspect that can also be facilitated and accelerated by governmental initiatives dedicated to set regulatory frameworks that promote sustainable businesses.

Fourth, connections to global value chains appear to play a more critical role in driving green entrepreneurship than for the case of overall KIE. This evidence confirms expectations that entrepreneurial firms in emerging markets might have increased benefits to tap into international markets, also benefiting from proximity to multinational companies – which are likely involved with organisational policies that favour environmentally sustainable initiatives (Potluri and Phani, 2020; Philp and Winickoff, 2017). Fifth, the role played by incubators and tech parks has also been associated with stronger impacts for green entrepreneurship, demonstrating the need for business support infrastructures to cultivate green entrepreneurial endeavours, confirming findings from Zeng et al. (2021) and Cohen (2006).

Last, it is important to notice that even successful ecosystems in our sample present weaknesses and incomplete sets of determinants in a comparison with EE located in developed nations (Alves et al., 2021). This lack of maturity is particularly noticeable for models associated with the intersection between green entrepreneurship and smart city applications. For this particular case, incubators and science parks can offer strategic assets for ecosystem evolution towards sustainable smart cities concepts (as in Barba-Sánchez et al., 2019). Yet, from our data, this relatively novel trend in urban planning has yet to find its way into mainstream public policy in the context of developing countries. Understanding the context in which these entrepreneurial events arise offers relevant insights on how to generate proper conditions and incentives for EEs to evolve in this specific area. This can ultimately have city-wide effects for sustainable transitions and, incidentally, for future entrepreneurial opportunities (Bifulco et al., 2016).

6 Concluding remarks

In this manuscript we have provided a novel body of evidence concerning the economic geography of green entrepreneurship. By addressing the case of a developing country, Brazil, we also move forward in understanding the operation of EEs in relatively laggard economies. The topic of environmentally sustainable entrepreneurship has become prominent in recent years due to increasing corporate awareness concerning agents' impacts on nature (Labella-Fernández, 2021). Hence, comprehending how myriad agents can combine efforts and promote such sort of KIE becomes a key strategy for regions to achieve sustainable development (O'Neill and Gibbs, 2016). Such aspects are even more critical *vis-à-vis* the fact that green entrepreneurs often require significant support to convert technical capabilities into actual economic competitiveness (Lazarevic et al., 2020).

Accordingly, our inquiry has underscored the differences and similarities between the observed dynamics taking place in EE concerning the emergence of overall KIE activity and green KIE – also looking into two subcohorts of the latter, namely green KIE applications to smart city concepts and bio-based KIE. Research universities lie at the core of ecosystems in all cases with enhanced effects moderated by their respective levels of interactions with industry. Thus, initiatives targeted at approximating academia and markets can offer vital assets for these ecosystems to thrive. In turn, for the specific case of green KIE, the development of support infrastructures (incubators and tech parks) is key. A straightforward implication in this case refers not only to developing these innovation habitats, but also in establishing strategies that guarantee dedicated space for tenants dealing with green technologies and sustainable business models.

Also, connections to global value chains can provide significant opportunities for green KIE. Looking into local-level strategies to foster internationalisation of businesses can be challenging, considering the relevant macroeconomic features that are at play. On the other hand, scanning and selecting multinational investments that can trigger green entrepreneurial activity at the host location is likely a valid way to address these issues. Last, we have observed that the emergence of green entrepreneurship still seems disconnected from aggregate technological strengths and flows. This poses some challenges in terms of maturing green ecosystems embedded in the context of a developing country.

Our findings, however, do not go without limitations. Although we have examined a consistent set of locations and their respective evolution over time, our estimations are based on a collection of variables that offer only a limited perspective on the complex interactions that take place within the domain of EEs. Also, by addressing entrepreneurial events through projects from a specific funding initiative, our representation can suffer from sample-selection bias. Hence, further inquiries on this field are necessary to advance our comprehension on the topic of green EEs. Complementary methodologies such as case studies, social network analysis and qualitative comparative analysis are also due in order to build a clearer picture concerning how ecosystems can better promote sustainable entrepreneurship. Inductive approaches that complement our exploratory view on this phenomenon are due in order to generate theory-driven contributions. This is vital to move forward in our understanding on the specificities of ecosystems of green entrepreneurship and to further understand how EE components connect to the generation of new ventures involved with sustainable transitions.

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Notes

1 Microregions comprise groups of cities (municipalities). These geographical units are designed to facilitate planning and management of public policies and services across the State of São Paulo.

Appendix

Table A1 Summary statistics

Variable	N		Min.		Max.		Mean		Median		St. dev. (within)		St. dev. (between)	
	Cities	*Micro-regions*	*Cities*	*Micro-regions*	*Cities*	*Micro-regions*	*Cities*	*Micro-regions*	*Cities*	*Micro-regions*	*Cities*	*Micro-regions*	*Cities*	*Micro-regions*
KIE	3,225	215	0.00	0.00	142.00	163.00	0.43	6.38	0.00	0.00	1.94	8.52	3.79	17.10
Green KIE	3,225	215	0.00	0.00	32.00	34.00	0.11	1.60	0.00	0.00	0.56	2.16	0.90	3.95
Smart city and green KIE	3,225	215	0.00	0.00	16.00	17.00	0.03	0.38	0.00	0.00	0.30	1.20	0.28	1.07
Bio-based KIE	3,225	215	0.00	0.00	21.00	22.00	0.07	1.09	0.00	0.00	0.39	1.48	0.56	2.50
Research university	3,225	215	0.00	0.00	1.00	1.00	0.06	0.61	0.00	1.00	0.06	0.11	0.22	0.48
Tertiary enrolment	3,185	215	0.00	0.00	0.21	0.03	0.01	0.01	0.00	0.01	0.00	0.00	0.02	0.01
Patents per capita	3,185	215	0.00	0.00	0.001	0.0001	0.00001	0.00001	0.00	0.00001	0.00	0.00001	0.02	0.00001
Technology transfer	3,185	215	0.00	0.00	0.0001	0.00	0.000002	0.000002	0.00	0.0000003	0.000007	0.000002	0.000008	0.000004
U-I interactions	3,225	215	0.00	0.00	1,545.00	1.641.00	5.58	83.67	0.00	3.00	18.24	75.07	56.74	218.88
SME share	3,225	215	0.90	0.97	1.00	0.99	0.98	0.98	0.99	0.99	0.01	0.002	0.01	0.004
Export-import activity	3,225	215	0.00	0.001	0.18	0.07	0.02	0.01	0.01	0.01	0.00	0.00	0.02	0.01
FDI	3,225	215	0.00	0.00	1.00	1.00	0.06	0.30	0.00	0.00	0.16	0.30	0.18	0.38

Table A1 Summary statistics (continued)

Variable	*N*		*Min.*		*Max.*		*Mean*		*Median*		*St. dev. (within)*		*St. dev. (between)*	
	Cities	*Micro-regions*	*Cities*	*Micro-regions*	*Cities*	*Micro-regions*	*Cities*	*Micro-regions*	*Cities*	*Micro-regions*	*Cities*	*Micro-regions*	*Cities*	*Micro-regions*
Incubators and tech parks	3,225	215	0.00	0.00	1.00	1.00	0.03	0.30	0.00	0.00	0.05	0.15	0.16	0.44
GDP per capita	3,185	215	2,590.30	5,293.50	280,100.00	82,916.00	18,985.00	19,198.00	14,320.00	16,925.00	12,333.00	9,622.50	14,675.00	7,029.50
Population	3,185	215	801	106,370	11,578,000	20,340,000	63,634	942,680	12,450	378,090	15,193	127,030	453,050	2,921,800
Population density	3,185	215	3.75	20.88	12,968.00	3,535.60	300.38	200.76	37.82	63.00	66.45	29.94	1,188.20	525.50
Credit availability	3,145	215	0.00	803.54	5,948,400.00	101,200.00	15,028.00	9,373.80	3,005.70	5,909.10	49,585.00	13,631.00	193,680.00	12,471.00
Energy consumption	3,185	215	0.34	1.04	347.08	23.61	2.71	2.71	1.68	2.04	2.41	0.65	11.53	2.85
Distance to main economic hub	3,225	215	0.00	40.85	758.00	655.00	343.66	328.65	352.00	314.16	0.00	0.00	183.37	175.06