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A Transdisciplinary Spatial Approach to Creating a Vibrant Entrepreneurial Ecosystem for Regional Development

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Abstract. Defining vibrancy as the levels of entrepreneurial activity promoted by the coordination of the network and the cooperation that represents an entrepreneurial ecosystem, practitioners and academicians have identified core attributes to create value based on the complex connection of factors to make it vibrant. Nevertheless, some ecosystems do not have efficient activity levels or are not well interconnected, preventing all stakeholders' total involvement or spillover (value creation and outcomes such as socio-economic development, well-being, and happiness). The contribution of this work is to use a transdisciplinary spatial method (used in measuring the spatial concentration of airline traveling) to measure the vibrancy of an entrepreneurial ecosystem. The framework procures the measurement of vibrancy and its sustainability for value creation in turbulent environments. A vibrant entrepreneurial ecosystem imbues regional development. A case will present a numerical comparison between the level of vibrancy between ecosystems and illustrations of its activity levels for the creation of networks and regional development.

Keywords. Collaborative design environments, regional development, socio-economic development, transdisciplinary approach, vibrancy

Introduction

Entrepreneurial Ecosystems (EEs) hold inter-related factors and forces that promote productive entrepreneurship in a specific space [1], entrepreneurial activity that leads to value creation and outcomes such as socio-economic development, well-being, happiness [2], and social capital flow [3]. Van de Ven initially proposed in 1993 four determinants of the ecosystem. These comprise regulating institutional arrangements, endowments of public resources of basic labor, finance, and scientific knowledge, informed consumers that create demand, and proprietary business activities [4]. Since then, several factors that comprise the ecosystem have been pointed out in this exciting genesis —mainly categorized in financial aspects, policy, human capital, markets, and culture [5] - [9]. These factors include network attributes such as interactions and interconnectedness that are important to EE productivity [10].

EE productivity creates value induced by dealmakers promoting the formation of networks. Dealmakers are players within the networks of an EE space with the role to "make connections from which knowledge spills over to lower costs of engaging in

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innovative activity, thus creating regional vibrancy" Feldman & Zoller, 2012, p.24 in [2]. The connection of said spatial network impact the vibrancy of EEs [11].

Considering vibrancy as the levels of entrepreneurial "activity" promoted by the coordination of the network or cooperation that represents the EE, a Vibrant EE (VEE) can be defined as "geographic areas that encourages and sustain high levels of entrepreneurial activity" [4] in [11], p.9. VEE thus is the collection and connection of isolated elements of EE operating in a location [12], [13] promoted by dealmakers [3], [12]. Practitioners and academicians [4], [12], [14], [15] have identified core attributes to create value based on the complex connection of factors to make a VEE and why some EEs thrive more than others in promoting entrepreneurial activities [11]. While Fluidity, Connectivity, Density and Diversity are the four main elements for EE Vibrancy; This study focuses on Connectivity because is transversal to ecosystems and is fundamental to creating a VEE [12]. The current study will focus on using "activity" levels to assess regional vibrancy. In addition, it aims to analyze dealmakers' inter-connections that create regional vibrancy. Some EE does not have high activity levels or are not well interconnected, preventing all stakeholders' total involvement or spillover. The rationale holds for any space, including digital environments. A definition for VEE is mentioned above, a "geographic area that encourages and sustains high levels of entrepreneurial activity" [4], but there are other definitions, and this is a challenge. The challenges rely on EE and VEE definitions, VEE measures and benchmarks, and conceptualization of digital EEs. The lack of theoretical models has a limited framework for structurally examining the flow of social capital. Although network analysis is a social science tool, it can help examine regional vibrancy from a transdisciplinary perspective. [3]

This paper is organized as follows: in Section 1, Structure of a VEE Model; Section 2, Connectivity in VEE; Section 3 presents a transdisciplinary spatial approach; Section 4 shows a methodology for measuring spatial concentration; Section 5 presents a case for assessing regional vibrancy. And Section 6 includes conclusions and managerial implications for regional development.

1. Structure of a VEE Model

VEE knowledge derives from the results of empirical studies. Audretsch & Belitski (2017) conducted a cross-sectional study of variations in entrepreneurship in seventy European cities using structural equation modeling and exploratory factor analysis from perception surveys on individuals [16]. The findings highlight that the individual factor is a crucial element of the VEE. Also, Auerswald & Dani (20017) studied the EEs adaptive lifestyle in the US National Capital Region (NCR). The authors suggest the role of fluidity, diversity, connectivity, and density in the EE as essential determinants of the regions' vibrancy [17]. Fluidity is determined by social capital flow in the EE. Diversity represents the rate of new knowledge produced in the region. Connectivity refers to the strength of the connections in the ecosystem, its flexibility to change, and absorptive capacity. Also, density represents the agglomeration of externalities that promote the region's growth. Further, Spigel (2017) studied relational elements of the EE using the case study method in Calgary, Waterloo, Alberta, and Ontario in Canada [18]. The finding suggests that the EE is constituted by the interplay between the social, cultural, and material elements allowing social capital flow, and knowledge. The study also recognized the role of skilled employees and experts in creating value in an EE. In addition, Barba-Sánchez et al. (2019) used the method of multiple regression to analyze

44 smart city initiatives in Spain [19]. The findings suggest the role of policies and communication technology as instrumental to the ecosystems' growth. The findings confirm the spillover effect of knowledge in the EE for regional development. Furthermore, Stam & Ven (2021) used a system framework to analyze the 12 Netherlands regions' EEs for 2009, 2012, and 2015. The findings suggest that ecosystems facilitate entrepreneurial actors in a diverse environment and how they interconnect to develop the ecosystem [20]. The results also indicate that output and productive entrepreneurship elements are independent. These include the resource endowments of demand. Further, the EE is dependent on networks.

A conceptual framework is presented in Figure 1.

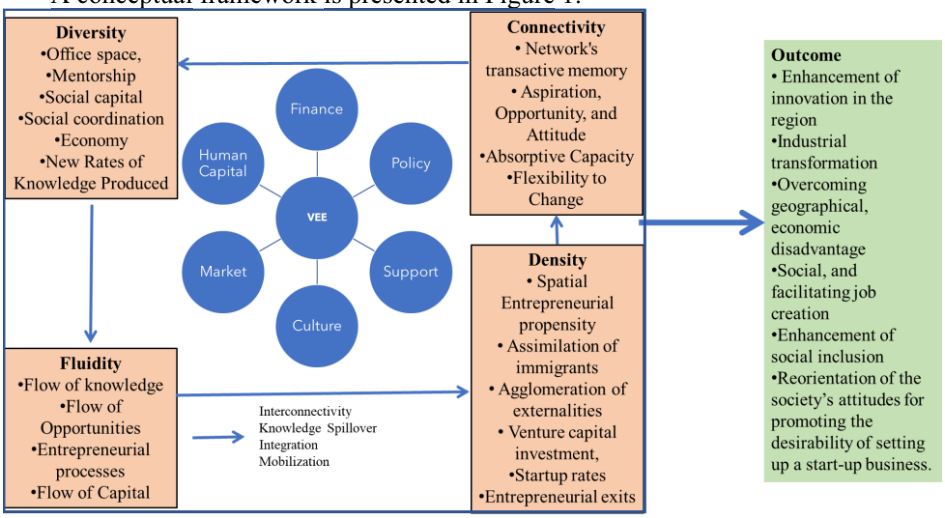

Figure 1. Own elaboration inspired on empirical literature review.

The empirical studies reviewed, and the literature analyzed remarks on the importance of networks for vibrancy in the EE. These include fluidity, density, diversity, and connectivity. These are impacted by six primary factors of finance, human capital, policy, support, culture, and market. The elements of vibrancy in the region must be integrated, interconnected, and mobilized to create spillover. The elements achieve outcomes by overcoming geographical location and economic disadvantages, facilitating social capital flow, reorientating the society's attitudes toward promoting regional vibrancy and the desirability of setting up a start-up business.

2. Connectivity in VEE

A key element of entrepreneurial vibrancy is connectivity, coherence, and coordination, representing the relationship between individuals, companies, and entrepreneurial programs in a region [15], [21]. The connectivity influences the network's transactive memory, which comprises meta-knowledge about entrepreneurship differentiated and shared between the firms in a specific space. It signifies the degree to which social networks linking EE participants, investors, entrepreneurs, support organizations, and other stakeholders are provided with the opportunity to interact and participate [22]. The factors of R&D, number of patents, capital access or support, governance, government financial support also add to the technological dynamism and build dynamic capabilities

for VEE, which creates entrepreneurial cognition and a co-creation ecosystem [23]-[27]. This cognition attribute will allow the EE to reconfigure itself to maintain vibrancy and growth.

Furthermore, the infrastructure component of a given space, including economic and social infrastructure factors, is also a key factor of VEE. The profitability, availability, and scalability of the infrastructure in a region impact investment intermediaries and legal structure facilitating EE [28], [29]. The catalyzing impact on VEE is also brought by the inclusion of large foundations and active (government) support to entrepreneurship activities in the form of legal structure enhancing exchangeability and transparency is further crucial [28]. The critical elements of people, technology, and infrastructure in a region, influenced by the four indicators comprising Fluidity, Connectivity, Density, and Diversity, impact an EE's vibrancy [12].

EE theoretical development can benefit from looking at EE phenomena through relationships approaches such as network theory, social network theory, and dynamic capabilities theory. An EE has interactions, relationships, interconnectedness, and interdependencies [10], [30]. Therefore, the variables to measure EE activity define vibrancy in an EE. Understanding vibrancy allows creating a VEE through frequent adaption and reconfiguration. We propose a spatial approach to define vibrancy in an EE. Cluster Theory, Process Theory, Resource Dependence Theory, Social Capital Theory, Systems Theory, Network Theory, Knowledge Spill Over Theory, Stakeholder Theory, Social Network Theory are relevant in EE. This suggests that the study of ecosystems is transdisciplinary by nature, focusing on relationships, interconnectedness, processes, systems, interdependencies, and interactions. [3], [31]

3. Transdisciplinary Spatial Approach

The elements of vibrancy in a region are integrated, interconnected, mobilized, and create spillover. The elements work towards the achievement of outcome which is inclusive of enhancement of innovation in the region, industrial transformation, overcoming geographical, economic disadvantage, social, and facilitating job creation, enhancement of social inclusion, reorientation of the society's attitudes for promoting the desirability of setting up a start-up business.

A cluster of startups represents the ecosystem itself with a spatial concentration of interconnected small firms. The lack of conceptualization regarding the spatial features of the ecosystem concept remains underdeveloped [27]. This article presents a model to conceptualize how interconnectivity increases "activity" within an EE using a spatial concentration model to define a measurement for vibrancy.

Vibrancy refers to the number of interactions between stakeholders. It is distributed among all the stakeholders when exchanging resources, ideas, processes, etc. A dense network of connections between a few programs and resources and entrepreneurs could be more effective than a not dense network of relationships between many resources, programs, and entrepreneurs. The patterns with no EE boundaries (different geographical spaces) are included when referring to networks. Thus, vibrancy can be defined as any spatial concentration. Connectivity for EE vibrancy can be observed by programs and resources connected with entrepreneurs within the ecosystem.

It is necessary to study the effectiveness of the use of resources in an EE spatial network (capabilities and services). A resource connectivity analysis can track this connectivity effectiveness comprising resource identification, resource concentration,

and resource allocation in the EE. Just as the densification process of the EE seeks to increase the number of sources of identified dealmakers, in the same way, in a VEE is necessary to know their location to manage connections. Moreover, seek to direct their benefits to the local space by physical relocation or digital integration/connection. Whether with local or external dealmakers/experts, the manager of the EE must be able to identify how sources can connect to generate mutual benefits between actors; the manager must consider that the connections do not need to be generated by himself. The manager must identify how to allow other sources of experts to generate those connections without his total involvement since he will not always have the installed capacity to follow up on them. This analysis leads to mobilizing own or other dealmakers' resources to generate these connections, where the manager must use his leadership and relational capital (manage social capital flow) so that these connections are really executed. The EE manager uses resources from this ecosystem to co-create dynamics and connection platforms between the sources to generate more significant opportunities for all ecosystem players (stakeholders). These connections would create a spillover effect of knowledge in the entrepreneurial ecosystem and facilitate value creation in the region due to social capital flow and regional vibrancy. EE vibrancy can be studied using various social science theories, and EE dynamics are systemic, allowing engineering tools to understand de behavior of the connections and dynamics. Understanding EE dynamics is important to create value and spillover to stakeholders and regional vibrancy. Stakeholders' theory examines the interconnections between business and those involved in its operation [32], and this work uses a spatial approach for understanding regional vibrancy [33]. The analysis and management of EE require Transdisciplinary Engineering; this is the challenge and using this approach provides large-scale solutions to complex problems and promotes a collaboration environment [34], [35].

4. A Model for Measuring Spatial Concentration using Gompertz Function

The EE defines the interconnected actors which have complex associations with different regions fosters towards promoting new business actions and entrepreneurship. As a sustainable entrepreneurship system contributes to supporting government at the regional or national level to support economic development, thus, many activities are aligned towards the creation of an entrepreneurial ecosystem [4]. Based on the arguments for measuring the spatial concentration, the Gompertz function growth curve-based model has been formulated to have the assessment of Vibrancy by examining connections. Connectivity herein serves as an important component contributing towards raising the frequency and service availability for the entrepreneurs, thus, the concentration is majorly dependent on connectivity [33]. With this linkage presence, the Gompertz model would be used to establish the linkage between EE activity and connectivity as not only does the model adds more flexibility in the computation of impact with its non-linear regression model but also is widely accepted for the state in the long-run relationship between different demand/connection variables.

The basic function of the Gompertz Growth Curve could be stated as model (1).

$$y_{x_t} = a_1 e^{\left(-a_2 e^{-a_3 x_t}\right)} \tag{1}$$

If A_{ij} denotes the exchanges or activity (i.e., services demanded from experts or dealmakers resulting in a transfer T of knowledge, resources, ideas, process, among others) between the ecosystem's stakeholders i and j, we define Aij as a relative measure of the "activity" between i and j, relative to the overall activities, such that a unidirectional connection is expressed as

$$A_{ij} = \frac{T_{ij}}{\sum_i \sum_j T_{ij}} \tag{2}$$

For each node k (marked in blue circles in Figure 2) in a specific space (stakeholder, hub, region, or ecosystem; physical or digital), we define α_k as the proportion of total "activity" directly linked to this node, such that we represent bidirectional connection (marked in red lines in Figure 2) expressed as

$$\alpha_k = \sum_i A_{i,k} + \sum_j A_{k,j} \tag{3}$$

By identifying the node of highest activity 'vibrant', we define the first vibrancy-index as β_1

$$\beta_1 = \alpha_{vibrant} = Max_i \alpha_i \tag{4}$$

β_1 'vibrancy' depends on the proportion of total ecosystem exchanges directly linked to the node with higher "exchangeability" (or mass of weighted activity). The upper bound occurs in the most concentrated situation were

$$\beta_1 = \alpha_{vibrant} = \sum_i A_{i,vibrant} + \sum_j A_{vibrant,j} = 1 \tag{5}$$

In the least concentrated situation, $A_{ij} = C$ for all $i \neq j$, where C is a Constant. So

$$\sum_j A_{1j} = \sum_j A_{2j} = \sum_j A_{3j} \tag{6}$$

And

$$\sum_i A_{i1} = \sum_i A_{i2} = \cdots = \sum_i A_{in} \tag{7}$$

Where, n is the number of nodes. This evenly distributed ecosystem (see Figure 2) defines the lower bound of $\beta_1 = \alpha_1 = \alpha_2 = \cdots = \alpha_n = 1/n$.

Figure 2. Network exchangeability/activity, Hypothetical example of evenly distributed spatial concentration based on [2] and [33].

Vibrancy refers to the number of interactions independent of the number of nodes. The measure is distributed among all nodes and does not increase in relation to the volume of the nodes. Therefore, Vibrancy can be defined as a spatial concentration. As an illustrative example, this work examines the Vibrancy index in the case of several EEs

connected with a digital platform. Within this rationale, EE vibrancy can be measured as the concentration of programs and services connection of mentors (experts) with entrepreneurs. A dense network of connections between a small number of programs and resources with entrepreneurs could be more efficient than a not dense network of connections between many resources and programs with entrepreneurs. According to Chou (1993) [33], a good mathematical approximation for spatial concentration is the Gompertz function to examine the β indexes of all possible numbers of nodes (the β curve). "the Gompertz function is suitable for approximating the β curve. This function not only satisfies the properties of the β curve, but also has straightforward computational procedures and well-defined mathematical properties" [36] in [33].

5. A Case for Assessing Regional Vibrancy

In model (1) wherein, a_1 represents the model saturation point while a_2 and a_3 depict the parameters which define the curvature of the shape of S-curve. Herein, as the focus is on building the linkage between connectivity and activity thus (in Figure 3) x represents the Connections (C) established while y denotes the EE Activity (EEA). EEA is (in general viewpoint corresponds to the flow of any factor of EE productivity) for this case, the number of visits from experts for stakeholders operating in different cities for example, in Table 1 for the case of Mexico we have Chihuahua, Monterrey, Mexico City, Guadalajara, San Pedro, Puebla, Leon, and for the US, Ashburn, Virginia. Therefore, using model (8) we can measure vibrancy in a VEE.

The presence of dealmakers or experts strongly predicts a vibrant regional economy. We are using the flow of experts into the region (their visits for what the platform keeps count). This analysis considers as dealmakers all the actors that operate within the EEs of Tecnologico de Monterrey in different cities. These experts make connections through services provided to entrepreneurs creating regional vibrancy and spillovers. [3]

The digital platform from which data was obtained is EOS (https://eossolution.io/en.html). The name stands for Entrepreneurship Operating System and is a system that tracks entrepreneurship projects in their different stages and manages the knowledge flow of entrepreneurship. It also connects experts with entrepreneurs and managers from the EE. Currently, there are more than 800 projects registered in 60 entrepreneurship programs that use this system for their development. EOS has more than 1,500 users in 17 Tecnologico de Monterrey campuses.

Table 1. Visits of experts from each city and services demanded, in a given period.

City	Number of Visits from Experts (EE Activity)	Number of Services Demanded by Entrepreneurs (Connections)
Chihuahua	128	25
Monterrey	74	12
Mexico City	36	10
Guadalajara	31	5
San Pedro	23	4
Puebla	23	4
Ashburn	20	3
Leon	18	2

$$EEA_{C_t} = 197.76 e^{\left(-2.8927\, e^{-0.0762 C_t}\right)} \quad (8)$$

The resulting factor (197.76) is vital because it can measure vibrancy and compare between ecosystems or regions by indicating saturation. The implications for ecosystem management are fostering growth by attracting skilled professionals and a greater flow of experts in the different industries that make up the ecosystem.

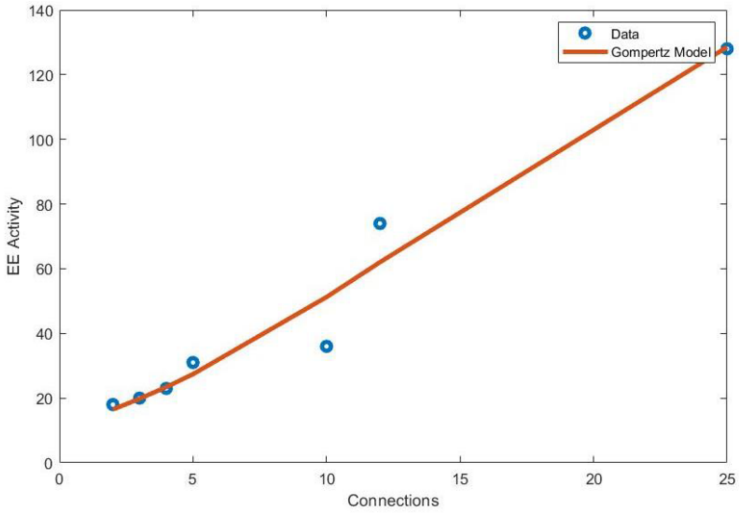

Figure 3. Entrepreneurial Ecosystem Activity.

Figure 3 shows that the city with the highest activity (EEA_{C_t}) given the same vibrancy-factor is Chihuahua, followed by Monterrey. A key managerial action is to increase the vibrancy-factor of the region, rather than increasing connections (C) to increase activity levels (EEA_{C_t}). An ideal way to address vibrancy is analyzing regions by grouping cities with higher interaction (closer in a physical or digital space of interaction).

It is important to point out that a higher density or number of connections (C) does not indicate more activity in the ecosystem or region (EEA_{C_t}). The latter happens by saturation point (a_1), which affects EE's vibrancy. This efficiency measure is associated with all the attributes inherent to the ecosystem and its management.

6. Conclusions and Managerial Implications for Regional Development

To generate a VEE it is essential to concentrate resources and build systemic conditions. The resources and needs are comprised, for density, of a high number of communities, new ventures, investors, skilled professionals, mentors, EE managers, and incubators focused on supporting the process of creating value and EEA. The connectivity is achieved by maintaining inter-relationships among founders, investors, talent, mentors, and experts/consultants. The role of the EE manager is to coordinate their interaction and codify tacit knowledge into resource management to keep the EE vibrant. Thus, vibrancy can be defined as spatial concentration.We propose that the connectivity effectiveness

can be tracked by a resource allocation analysis with resources identification, concentration, and allocation in a VEE and measure its impact on Regional Development. This flexibility will allow the EE to reconfigure itself to maintain vibrancy and growth. Some of the challenges to VEE sustainability are the definition of governance and policy-making guidelines, which is why it is essential to have a systemic understanding of VEE. An EE in a turbulent environment must be flexible to sustain vibrancy and keep value creation. For further research, there are different perspectives to keep working with creating vibrancy in a region. According to definitions formulated in this work, one approach could apply machine learning techniques to predict the entrepreneurial vibrancy of cities. Another crucial economic approach is to examine VEE dynamic capabilities (VEEDC) and how to manage it. VEEDC has an impact on the performance of a VEE. Its resources, knowledge management, alliances, entrepreneurial orientation, and environmental dynamism are the elements that enable it. An evolutionary approach is of value to balance exogenous and endogenous factors to build robust VEEDC when taking "make" or "buy" decisions for services demanded by entrepreneurs. One last approach is the exploration of online-offline EEs models (physical and digital spaces) within the gaming domain to increase activity through bringing and bonding to reinforce connections and increase spatial vibrancy, and thus regional vibrancy.

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