Causal Model and Causal Inference for Entrepreneurial Ecosystem Success: *A Bayesian Network Approach applied to Iranian EEs*

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Abstract:

Entrepreneurship is an essential driver of a dynamic and successful industry. Similarly, an entrepreneurial ecosystem is the ability of a territory to create a system of internal elements, supporting the creation and development of productive entrepreneurship. Despite its importance, the literature on the internal relationship of entrepreneurial ecosystem elements and their causal effect on entrepreneurship outcomes is limited to a few theoretical, but inspiring articles. Therefore, this research aims to develop a Bayesian network model of the causal relationships between entrepreneurial ecosystem elements and entrepreneurship outcomes based on Iranian field data and provide a Bayesian inference analysis to answer critical questions such as: What is the causal effect of entrepreneurial ecosystem elements on entrepreneurship outcomes? Which configuration of a regional entrepreneurial ecosystem would be more effective than others? With what probabilities? In addition, for a certain level of risk of success, what configuration of a regional entrepreneurial ecosystem would be recommended?

Classification JEL : L26, C11, C36, R58, D83, D84

Keywords: Entrepreneurial Ecosystem, Causal Models, Bayesian Networks, Bayesian Inference, Expert Knowledge.

1 Introduction

In the entrepreneurship literature, attention has been paid recently to the role of Entrepreneurial Ecosystems (EEs) and their contribution to relevant economic outcomes (Stenholm et al., 2013; Mason and Brown, 2014; Ács et al., 2017; Lafuente et al., 2018; Szerb et al., 2013, 2017, 2019, 2020; Lafuente et al., 2020). Rather than using standard entrepreneurship metrics, these studies point to the need to analyze the entrepreneurial context. The premises of these works can be found in the paper of Gnyawali and Fogel, who defined the dimensions of the entrepreneurial context as early as 1994. It includes socioeconomic factors, the entrepreneurial and commercial skills of the project promoters, the level of financial assistance, and institutional and governmental policies and procedures (Abdesselam et al., 2017, 2020). Aparicio et al. (2016) found that informal factors (attitudes towards entrepreneurship, perceived corruption, confidence in one's own capacities, etc.) have a stronger impact on entrepreneurial activity than formal factors (procedures and costs of creating a business, access to credit, etc.). Chowdhury et al. (2019) examined how formal and informal institutional dimensions can affect economic development, demonstrating that institutions are important for both the quality and the quantity of entrepreneurship.

Other studies have also shed fresh light on the concept of EEs (Mason & Brown, 2014; Stam, 2018). Based on biological analogy, they seek to encompass all the links shared by each institution in the ecosystem that foster the territory's sustainable and scalable innovative performance. Autio et al (2014) define an EE as a territory made up of institutions that promote the emergence and monitoring of new businesses, involving individuals with strong innovation competencies that help to develop entrepreneurship. The EEs are comprised of a set of interconnected entrepreneurial actors (companies, business angels, universities, etc.) and entrepreneurial processes (propensity to set-up a firm, entrepreneurial mindset, etc.) that formally or informally combine to foster performance within a local entrepreneurial environment (Mason & Brown, 2014; Autio et al., 2018; Malecki, 2018).

EEs are about the capacity of a territory to create a system of actors and infrastructures supporting the creation and development of innovative business projects, beyond the simple construction of a network structure between companies (Nicotra et al., 2018). Based on the open systems view, entrepreneurial ecosystems have inputs and outputs, also internal elements with interactions that make diverse configurations. Therefore, as Wurth et al. (2021) point out, these systems are to some extent dependent or sensitive to external conditions. This means that we should expect substantial heterogeneity in the inputs required to build a well-functioning entrepreneurial ecosystem (Wurth et al., 2021). Different internal ecosystem configurations can thus lead to different outcomes known as productive i.e. that directly or indirectly contribute to the net output of the economy or the ability to produce additional output and increase overall well-being (Brown & Mawson, 2019, Nicotra et al., 2018). Ecosystems rich in entrepreneurial resources (strong) and with a structure that facilitates the flow of these resources (well-

functioning) will see higher rates of innovative and growth-oriented entrepreneurship that contribute to economic growth and economic resilience (Spigel & Harrison, 2018).

Despite the significant growth of the entrepreneurial ecosystem (EE) literature, it has been largely typological and atheoretical (Spigel & Harrison, 2018). The rush to employ the entrepreneurial ecosystem approach has gotten ahead of answering many fundamental conceptual, theoretical, and empirical questions (F. C. Stam & Spigel, 2016). The result is only long lists of relevant factors of successful entrepreneurial ecosystems, without clear explanations of causal relationships (Nicotra et al., 2018; F. C. Stam & Spigel, 2016). Moreover, local contexts are considered important, but relatively little is known about how and to what extent the link between entrepreneurship and growth may depend on local contexts (Content et al., 2020). These approaches do not offer sufficient explanations for economic outcomes and have not been delineated (F. C. Stam & Spigel, 2016). As a result, the literature on entrepreneurial ecosystem factors driving productive entrepreneurship is largely based on researchers' direct experiences without empirically embracing causalities (Nicotra et al., 2018).

Recently, some researchers have attempted to fill the previously mentioned gaps in the causal explanation of the entrepreneurial ecosystem and productive entrepreneurship. Stam (2015) provided a new synthesis including a causal schema of how the systemic setting and conditions of the ecosystem lead to particular entrepreneurial activities outputs and new value creation outcomes. His model builds on the ideas of the previous literature, but offers greater causal depth with four ontological layers (setting conditions, systemic conditions, outputs, and outcomes), including bottom-up and top-down causality, and intra-layer causal relationships. Nicotra et al. (2018) proposed a framework to measure and test the causal effects of a set of entrepreneurial ecosystem factors (eco-factors) on productive entrepreneurship (eco-output). Their study was based on a literature review, and they did not test this framework empirically. The other significant work on causality in the entrepreneurial ecosystem is by Wurth et al. (2021). They used the recent literature on this topic and developed causal mechanisms that were mainly proposed by Stam (2015). In particular, they added the interaction between different ecosystems and the flow of resources and information between them.

Subsequently, the review of the entrepreneurial ecosystem and some insights from some renowned authors (see Nicotra et al, 2018; Stam, 2015 and Wurth et al, 2021) reveal that the current stock of empirical research does not clearly answer the questions below:

- What are the causal relationships between the physical and non-physical elements of regional entrepreneurial ecosystems? What are the contingencies?

- What is the causal effect of the entrepreneurial ecosystem on productive performance and other outcomes at the regional level?

- Which configuration of a regional entrepreneurial ecosystem would be more effective than others? With what probabilities?

- For a certain level of risk of success, what configuration of a regional entrepreneurial ecosystem would be recommended?

Therefore, the objective of this research proposal is to develop a causal model of regional entrepreneurial ecosystems and productive entrepreneurship with causal inference capability, which can provide sophisticated answers to the above four questions. To achieve this goal, the methodologies proposed here are Bayesian network and Bayesian inference methods and algorithms, which will be explained in more detail in the methodology section.

2 Methodology

2.1 Research method

The methodology for this research is Bayesian network and Bayesian inference. A Bayesian network consists of a structure of arcs and nodes known as the qualitative part and a set of conditional probability distributions known as the quantitative part (Azhdari, 2018). Both the qualitative and quantitative parts can be generated from the field data or the domain knowledge of experts, or a combination (Amirkhani et al., 2017; Kudikyala et al., 2018).

Dependencies in a Bayesian network are represented by a Directed Acyclic Graph (DAG) and "quantified" by a joint probability distribution, which decomposes into a product of local conditional distributions in equation 1 (Gross et al., 2019):

$$p(X_1, X_2 \dots, X_n) = \prod_{i=1}^{n} p(X_i | Pa_{x_i}) \qquad (1)$$

where Pa_{xi} is the set of parents of Xi. The most important application of a Bayesian network is probabilistic inference, i.e., estimating the posterior probability P(X|Y) on target variables X given evidence on other variables Y (Scanagatta et al., 2019).

When the field data are scarce or hard to gather, which is the case here for entrepreneurial ecosystems of Iran, the knowledge elicitation from domain experts to develop a Bayesian network is an effective solution. Various methods are used in the literature to elicit domain knowledge from experts (Bulmer et al., 2022; Kleemann et al., 2017; Diallo et al., 2015; Xiao-xuan et al., 2007; Nadkarni & Shenoy, 2004). The proposed procedures of Nadkarny and Shenoy (2004) and Xiao-xuan et al. (2007) are good examples of the knowledge elicitation methods, consequently applied here. Therefore, the adopted workflow in this study is as depicted in figure 1.

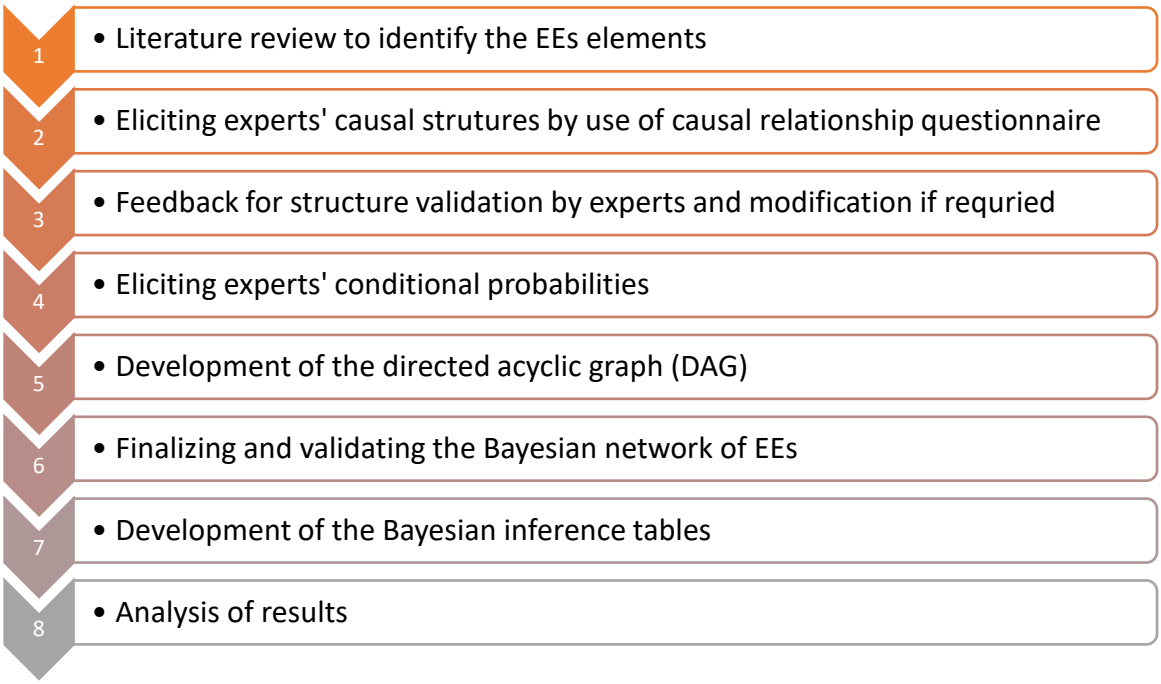

Figure 1 The workflow of the research

As illustrated in figure 1, after stage 4, the network may require some changes to eliminate the causal cycles into a directed acyclic graph (DAG). The network needs to be a DAG for the application of Bayesian inference algorithms. Accordingly, the entrepreneurship outputs of various configurations of entrepreneurial ecosystems can be predicted (forward inference). Also, the required arrangements for entrepreneurial ecosystems of intentional entrepreneurship outputs could be determined (backward inference). Finally, some configurations can be developed which can be a benchmark for regional entrepreneurship excellence with the most probabilities of success.

In the process of the Bayesian network development and Bayesian inferences, some software might be needed. The software such as TETRAD (Ramsey et al., 2018), and R packages of bnlearn (Scutari, 2009; Scutari, Scutari, et al., 2019) and bayesm (Rossi et al., 2019) are include the required algorithms for the aim of this research.

2.2 The validity of the model

However, in many cases such as this study, the Bayesian network is developed with a lack of field data. Therefore, the proposed validation framework of Pitchforth and Mengerson (2013) be applied to validate the resultant Bayesian network.

2.2 Data collection

As mentioned in the research method, this research uses expert knowledge to develop the Bayesian network of Iranian EEs. Iran is one of the significant economies in the middle-east, which usually was heavily relied on oil exports. Under new conditions, Iran's economy needs to count more on entrepreneurship to be resilient. As the entrepreneurs are the best ones who

exactly experienced the entrepreneurial ecosystems of their regions, the required data for this research is the domain knowledge of more than 25 experts who are successful entrepreneurs in some industrial zones near Tehran, Iran's capital.

The domain knowledge to map the causal relations of the conditions of entrepreneurial ecosystems can be gathered by a causal relationships questionnaire (Xiao-xuan et al., 2007). The measurement model developed by Sternberg et al. (2019) is a good source for this questionnaire development task. This model is based on the earlier framework of Stam (2015) and consists of the division of framework conditions and systemic conditions (Sternberg et al., 2019). The framework conditions include the social (informal and formal institutions) and the physical conditions, enabling or constraining human interaction. The systemic conditions include networks of entrepreneurs, leadership, finance, talent, knowledge, and support services (Sternberg et al., 2019).

The success of entrepreneurship that is affected by conditions of an entrepreneurial ecosystem also needed to be embedded in the above causal relationships questionnaire. The related variables can be adopted from REDI issued of Global Entrepreneurship Index (GEI), which has been developed by Ács, Szerb and their team according to the fact that individuals are always embedded in a given regional context (Ortega-Argilés et al., 2013).

The conditional table of each node requires to be constructed by eliciting experts' opinions. The conditional probability questionnaires for each node need to be developed for this task. Some interviews are expected for this job, as this may be obscure for some experts.

The required data for the validation process of the final Bayesian network will be provided by experts.

3 Results

Previous research on entrepreneurship has largely neglected the local, ecosystem-specific interaction of factors influencing entrepreneurship due to a focus on analyzing one or a few isolated influencing factors (Hubner et al., 2021). Elaborating a causal model of regional entrepreneurial ecosystems and productive entrepreneurship with causal inference capability can provide sophisticated responses to the four questions above. Although causal mechanisms in the entrepreneurial ecosystem and their effects on entrepreneurial outputs are vital (Nicotra et al., 2018; E. Stam, 2015; F. C. Stam & Spigel, 2016; Wurth et al., 2021) the literature on entrepreneurial ecosystem factors that cause productive entrepreneurship are scarce, also non-empirical. Besides, answering the causal questions mentioned before are highly critical to researchers, regional policymakers, and entrepreneurs. Therefore, implementation of this research proposal at least would bring about contributions below:

It contributes to the theoretical body of knowledge of entrepreneurship, by providing some significant explanations about causation mechanisms and contingencies in the regional entrepreneurial ecosystem and productive entrepreneurship realm.

For the first time this work would bring about the inferential knowledge in entrepreneurship context, providing some potentials for objective risk analysis, which were less likely to imagine before.

The use of Bayesian networks and Bayesian inference in entrepreneurial ecosystem research would be a new methodological development in this field and lead to numerous other research opportunities, providing deeper and wider knowledge about entrepreneurial ecosystems and related concepts.

This research can fill the gap of knowledge about the dynamics of the regional entrepreneurial ecosystems of Iran. In addition, this work can be a tool to gather some of the valuable domain knowledge of regional entrepreneurs and systematically report them.

Finally, this study would be preliminary research for a more comprehensive one: a causal Bayesian network learning and inference in a wider context with field data, which deepens the causal knowledge of entrepreneurial ecosystems and their impacts on productive entrepreneurship.

4 References

Abdesselam, R., Bonnet, J., & Renou-Maissant, P. (2020). What are the drivers of business demography and employment in the countries of the European Union?. *Applied Economics*, 1-26.

Abdesselam, R., Bonnet, J., & Renou-Maissant, P. et M. Aubry (2017), "Entrepreneurship, Economic Development and Institutional Environment: Evidence from OECD countries", *Journal of International Entrepreneurship*, 16, 1-43. https://link.springer.com/content/pdf/10.1007%2Fs10843-017-0214-3.pdf.

Ács, Z. J., Stam, E., Audretsch, D. B., & O'Connor, A. (2017). The lineages of the entrepreneurial ecosystem approach. Small Business Economics, 49(1), 1-10.

Amirkhani, H., Rahmati, M., Lucas, P. J. F., & Hommersom, A. (2017). Exploiting Experts' Knowledge for Structure Learning of Bayesian Networks. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *39*(11), 2154–2170. https://doi.org/10.1109/TPAMI.2016.2636828

Aparicio, S., Urbano, D., & Audretsch, D. (2016) Institutional factors, opportunity entrepreneurship and economic growth: Panel data evidence. Technological Forecasting and Social Change, 102, 45-61. DOI: 10.1016/j.techfore.2015.04.006

Argiles, R. O., Acs, Z. J., Szerb, L., Autio, E., & Komlosi, E. (2014). *REDI: The Regional Entrepreneurship and Development Index–Measuring regional entrepreneurship Final report*.

Autio, E., Kenney, M., Mustar, P., Siegel, D., & Wright, M. (2014) Entrepreneurial innovation: The importance of context. Research Policy, 43(7), 1097-1108. DOI: 10.1016/j.respol.2014.01.015

Autio, E., Szerb, L., Komlosi, E., & Tiszberger, M. (2018). The European Index of Digital Entrepreneurship Systems. DOI, 10, 39256.

Azhdari, B. (2018). A Bayesian Inference Analysis of Supply Chain Enablers, Supply Chain Management Practices, and Performance. *International Conference on Operations Research and Enterprise Systems*, 37–53.

Brown, R., & Mawson, S. (2019). Entrepreneurial ecosystems and public policy in action: A critique of the latest industrial policy blockbuster. *Cambridge Journal of Regions, Economy and Society*, *12*(3), 347–368.

Bulmer, R. H., Stephenson, F., Lohrer, A. M., Lundquist, C. J., Madarasz-Smith, A., Pilditch, C. A., Thrush, S. F., & Hewitt, J. E. (2022). Informing the management of multiple stressors on estuarine ecosystems using an expert-based Bayesian Network model. *Journal of Environmental Management*, *301*, 113576. https://doi.org/10.1016/j.jenvman.2021.113576

Content, J., Bosma, N., Jordaan, J., & Sanders, M. (2020). Entrepreneurial ecosystems, entrepreneurial activity and economic growth: New evidence from European regions. *Regional Studies*, *54*(8), 1007–1019. https://doi.org/10.1080/00343404.2019.1680827

Diallo, T. M. L., Henry, S., & Ouzrout, Y. (2015). Bayesian Network Building for Diagnosis in Industrial Domain based on Expert Knowledge and Unitary Traceability Data. *IFAC-PapersOnLine*, *48*(3), 2411–2416. https://doi.org/10.1016/j.ifacol.2015.06.449

Gnyawali, D. R., & Fogel, D. S. (1994) Environments for entrepreneurship development: key dimensions and research implications. Entrepreneurship theory and practice, 18, 43-43. DOI: 10.1177/104225879401800403.

Gross, T. J., Bessani, M., Darwin Junior, W., Araújo, R. B., Vale, F. A. C., & Maciel, C. D. (2019). An analytical threshold for combining Bayesian Networks. *Knowledge-Based Systems*, *175*, 36–49. https://doi.org/10.1016/j.knosys.2019.03.014

Hubner, S., Most, F., Wirtz, J., & Auer, C. (2021). Narratives in entrepreneurial ecosystems: Drivers of effectuation versus causation. *Small Business Economics*. https://doi.org/10.1007/s11187-021-00531-3

Kleemann, J., Celio, E., Nyarko, B. K., Jimenez-Martinez, M., & Fürst, C. (2017). Assessing the risk of seasonal food insecurity with an expert-based Bayesian Belief Network approach in northern Ghana, West Africa. *Ecological Complexity*, *32*, 53–73. https://doi.org/10.1016/j.ecocom.2017.09.002

Kudikyala, U. K., Bugudapu, M., & Jakkula, M. (2018). Graphical Structure of Bayesian Networks by Eliciting Mental Models of Experts. In *Smart Computing and Informatics* (pp. 333–341). Springer.

Lafuente, E., Ács, Z.J., Sanders, M., & Szerb, L. (2020). The global technology frontier: productivity growth and the relevance of Kirznerian and Schumpeterian entrepreneurship. Small Business Economics, 55, 153-178.

Lafuente, E., Szerb, L., & Ács, Z. J. (2018). The entrepreneurship paradox: More entrepreneurs are not always good for the economy–The role of the entrepreneurial ecosystem on economic performance in Africa. *Available at SSRN 3307617*.

Malecki, E. J. (2018). Entrepreneurship and entrepreneurial ecosystems. *Geography Compass*, *12*(3), e12359.

Nadkarni, S., & Shenoy, P. P. (2004). A causal mapping approach to constructing Bayesian networks. *Decision Support Systems*, *38*(2), 259–281. https://doi.org/10.1016/S0167-9236(03)00095-2

Nicotra, M., Romano, M., Del Giudice, M., & Schillaci, C. E. (2018). The causal relation between entrepreneurial ecosystem and productive entrepreneurship: A measurement framework. *The Journal of Technology Transfer*, *43*(3), 640–673.

Ortega-Argilés, R., Szerb, L., Acs, Z., Komlosi, E., & Autio, E. (2013). *REDI: The Regional Entrepreneurship and Development Index – Measuring regional entrepreneurship*.

Pitchforth, J., & Mengersen, K. (2013). A proposed validation framework for expert elicited Bayesian Networks. *Expert Systems with Applications*, *40*(1), 162–167. https://doi.org/10.1016/j.eswa.2012.07.026

Ramsey, J. D., Zhang, K., Glymour, M., Romero, R. S., Huang, B., Ebert-Uphoff, I., Samarasinghe, S., Barnes, E. A., & Glymour, C. (2018). TETRAD—A toolbox for causal discovery. *8th International Workshop on Climate Informatics*.

Rossi, P., Rossi, M. P., Rcpp, I., Rcpp, L., SUR, B. S. U. R., MNL, M. L., & MNP, M. P. (2019). *Package 'bayesm.'*

Scanagatta, M., Salmerón, A., & Stella, F. (2019). A survey on Bayesian network structure learning from data. *Progress in Artificial Intelligence*, *8*(4), 425–439. https://doi.org/10.1007/s13748-019-00194-y B. Azhdari Research Proposal

Stam, E. (2018). Measuring entrepreneurial ecosystems. *In Entrepreneurial ecosystems* (pp. 173-197). Springer, Cham.

Stenholm, P., Ács, Z. J., & Wuebker, R. (2013) Exploring country-level institutional arrangements on the rate and type of entrepreneurial activity. Journal of Business Venturing, 28(1), 176-193. DOI: 10.1016/j.jbusvent.2011.11.002

Szerb, L., Ortega-Argilés, R., Acs, Z. J., & Komlósi, É. (2020). Optimizing entrepreneurial development processes for smart specialization in the European Union. *Papers in regional science*, 99(5), 1413-1457. https://doi.org/10.1111/pirs.12536

Szerb, L., Lafuente, E., Horváth, K., & Páger, B. (2019). The relevance of quantity and quality entrepreneurship for regional performance: The moderating role of the entrepreneurial ecosystem. Regional Studies, 53(9), 1308-1320. DOI: 10.1080/00343404.2018.1510481

Szerb L., Komlósi É. and Páger B. (2017) A Multidimensional, Comparative Analysis of the Regional Entrepreneurship Performance in the Central and Eastern European EU Member Countries. Entrepreneurship in Transition Economies (pp. 35-56) Springer International Publishing

Szerb, L., Ács, Z., Autio E., Ortega-Argilés R. and Komlósi É. (2013) The Regional Entrepreneurship and Development Index–Measuring regional entrepreneurship

Xiao-xuan, H., Hui, W., & Shuo, W. (2007). Using Expert's Knowledge to Build Bayesian Networks. *2007 International Conference on Computational Intelligence and Security Workshops (CISW 2007)*, 220–223. https://doi.org/10.1109/CISW.2007.4425484