

The Role of Innovation Ecosystems in SMEs’ Industry 4.0 Transformation

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Summary: The transition to Industry 4.0 presents a significant challenge for small and medium-sized enterprises (SMEs), requiring strategic adaptation and engagement with innovation ecosystems. While previous research highlights the enabling role of these ecosystems in supporting SMEs' transformation in the context of Industry 4.0, limited empirical evidence exists on how managers perceive and mobilise them in practice. Our study addresses this gap by examining how industrial SMEs' managers engage with the Industry 4.0 innovation ecosystem, based on 27 semi-directive interviews. Preliminary findings reveal diverse managerial attitudes, ranging from scepticism regarding the ecosystem's practical utility to long-term collaboration with key actors. The ways in which SMEs' managers leverage external support for Industry 4.0 implementation also vary, from ad hoc solutions addressing specific needs to comprehensive, multi-level strategic collaborations.

Track: Organisational Transformation Change and Development

Word count: 2070

Introduction

Originated as a policy-driven initiative, Industry 4.0 (I4.0) was aimed at revitalising the German manufacturing sector by fostering the integration of digital technologies into industrial production (Pfeiffer, 2017). The concept emerged as a response to economic challenges, particularly the 2009 financial crisis, and was designed to create conditions that would enhance productivity and global competitiveness of companies (Reischauer, 2018). Beyond its technological scope, I4.0 promoted multi-level collaboration among government bodies, educational institutions, industry associations, media, and consulting firms—forming an innovation ecosystem that shapes and encourages shared understandings and implementations of I4.0 (Fogaça et al., 2025; Scott, 2014). This vision quickly spread internationally, shaping many national industrial strategies (Castelo-Branco et al., 2023). In the European Union alone, 28 national initiatives have been launched to stimulate the digitalisation of industrial economies, with a particular emphasis on small and medium-sized enterprises (SMEs), given their fundamental role in the economies of most member states (Teixeira and Tavares-Lehmann, 2022).

In this context of widespread encouragement, and sometimes pressure, for firms to transition towards I4.0, an increasing number of SMEs are navigating this transformation. The latter can manifest in diverse ways, ranging from incremental technological improvements (Mittal et al., 2020), to radical changes (Vereycken et al., 2024). During this transformation, SMEs' managers often face significant challenges, given constraints in financial and human resources, limited strategic planning time, and varying levels of expertise in change management (Horváth and Szabo, 2019; Sony et al., 2024). Scholars emphasise that one of the key avenues for addressing these challenges lies in fostering collaborations between SMEs' managers' and actors within their respective innovation ecosystems (Benitez et al., 2020).

Previous research has highlighted the enabling role of innovation ecosystems in supporting SMEs' engagement with I4.0. For instance, governmental subsidies and fiscal incentives can alleviate SMEs' financial constraints, while partnerships with universities, technology providers, and consulting firms can facilitate access to digital expertise (Somohano-Rodríguez et al., 2022). Some studies also highlighted internal and external to SMEs barriers that may prevent managers to benefit from the advantages of innovation ecosystem when implementing I4.0. Besides inner constraints such as lack of awareness about existing initiatives or trusting issues to share their innovation experiences (Cugno et al., 2021), SMEs' managers face bureaucratic systems that are too complex to navigate or too long to evaluate tenders (Horváth and Szabo, 2019). Although these findings already deliver an overall view of innovation ecosystems role in SMEs' I4.0 transformation, several critical research gaps remain.

Firstly, there is limited empirical evidence on how SMEs' managers perceive the role of the innovation ecosystem in their I4.0 transformation. Current studies tend to focus on perspectives from ecosystem actors such as policymakers, technology providers, or competence centres (Benitez et al., 2020), or from firms that have successfully engaged with the ecosystem and experienced positive outcomes (Santos et al., 2022). As a result, these actors are generally presented as major help in fostering SMEs' successful transition to I4.0. However, from a sensemaking perspective (Weick, 1995), innovation ecosystems are more than objective givens as they are interpreted through managerial lenses shaped by past experience, contextual fit, and perceived usefulness. In this process, managers act as sense-makers: they interpret what is offered in relation to their firms' needs and specifics, by extracting cues and retrospectively assigning meaning to justify their action (Balogun et al., 2015; Weick, 1995). Thus, a more nuanced understanding of how SMEs' managers make sense of the innovation ecosystem for I4.0 implementation remains largely overlooked and calls for an empirical investigation.

Secondly, little attention has been paid to the way SMEs' managers navigate the innovation ecosystem during I4.0 transformation. Existing literature often conceptualises these interactions from an isomorphic perspective, suggesting that SMEs conform to the standardised support structures promoted by the ecosystem (DiMaggio and Powell, 1983), such as adoption of key I4.0 technologies (Ricci et al., 2021) or human-centric practices (Ietto et al., 2024). Yet, firms may respond strategically to institutional pressures, ranging from passive compliance to more active forms of resistance, avoidance, or manipulation (Oliver, 1991). This reframes the relationship between SMEs and the ecosystem as a space of strategic negotiation, especially when external expectations conflict with SMEs' context or diverge from their priorities. In such a space, managers can develop diverse strategies by interpreting ecosystems' logics in light of their own perceptions and SMEs' capabilities (DeKrey and Portugal, 2014; Weick, 1995). These less confirmative, more interpretive approaches of managerial interaction with innovation ecosystems for I4.0 transformation remain overlooked and require further empirical inquiry.

Bridging these gaps, this study aims to explore the following research questions:

How SMEs' managers perceive and navigate the innovation ecosystem for I4.0 implementation?

In the next sections, we outline the methodology used for data collection and analysis to address these research questions. This is followed by a discussion of the preliminary results, providing initial insights into SME managers' perspectives on the role of innovation ecosystems in I4.0 implementation. Finally, we reflect on the future development of the study, highlighting potential directions for further analysis and refinement.

Methodology

To examine how SMEs' managers perceive and mobilise the innovation ecosystems in their strategies for I4.0 transformation, we conducted semi-directive interviews with managers of Walloon industrial SMEs. This geographical context is particularly relevant, as Wallonia, the French-speaking region of Belgium, has been strongly engaged in national policies supporting SMEs in their digital transition (Teixeira and Tavares-Lehmann, 2022). A variety of actors and initiatives exist to facilitate I4.0 implementation among SMEs in Walloon region. Public agency for digital transformation, technology industry federation, and industry-specific competitiveness clusters work together to provide technological, financial, and training support through initiatives like *Industrie du Futur* and *Factory of the Future* (SPW and Agence du Numérique, 2021).

To structure the data collection, we developed an interview guide consisting of predominantly open-ended questions within a predefined set of themes. These covered the firms' I4.0 transformation experiences, interactions with the innovation ecosystem, and the outcomes of these engagements. The selection of participants was based on criteria such as company size (fewer than 250 employees), industrial sector, ownership type, I4.0 maturity level, ensuring their involvement or interest in I4.0. The final sample comprised 27 respondents from 22 SMEs, active in a wide range of manufacturing (18) and waste management sectors (5). Firm sizes ranged from 8 to 135 employees, with family- and group-types of ownership. In terms of I4.0 maturity, the sample covered 13 advanced, 5 starting, and 4 non-adopting firms.

Following data collection, we proceeded with data analysis. The first step involved transcription of the interviews. Next, we applied an iterative coding process (Saldaña, 2016). The initial phase of open coding allowed for the identification of key themes and concepts emerging from the data. We then engaged in axial coding, seeking connections between categories to refine our understanding of how SMEs' managers engage with innovation ecosystems in their I4.0

strategies. This process is ongoing, with the next step focusing on selective coding to integrate findings into a cohesive analytical framework.

Preliminary results

All participating SMEs are engaged in I4.0 transformation at different stages. While some are still in the early phases of strategic reflection and planning, others are actively implementing digital technologies. A smaller group, comprising the most advanced firms, is close to has the full I4.0 transition. This spectrum of engagement highlights the varying levels of digital maturity among SMEs and the different trajectories they can take in navigating transformation.

Most SMEs' managers demonstrate at least some awareness of I4.0 initiatives and key actors within the regional innovation ecosystem, though the depth of knowledge varies considerably. Managers who lack familiarity with the ecosystem are predominantly from international group subsidiaries, where corporate headquarters often dictate strategic directions. Among those who have engaged with the ecosystem, experiences are mixed. Some have successfully collaborated with ecosystem actors, while others report unsuccessful interactions. The reasons for non-engagement typically stem from three primary concerns: a perception that existing support mechanisms do not align with their needs, an inability to allocate time and resources for collaboration, or ineligibility for financial aid due to their classification under the European legal definition of SMEs.

The political nature of the I4.0 ecosystem remains a recurring theme in managers' discourse, influencing how they position themselves towards key ecosystem actors. While some adopt a critical stance, others are more neutral or even highly engaged. The sceptics perceive the ecosystem as largely performative, designed to showcase public funding allocations rather than to provide meaningful support for SMEs. They argue that initiatives multiply without effectively addressing fundamental issues, leaving SMEs without practical guidance. This frustration often manifests in statements questioning the rationale behind promoting digitalisation while broader economic and political structures remain unchanged. In contrast, a more neutral-to-convinced group acknowledges the benefits of collaboration and provides examples of successful interactions, though they do not universally endorse the ecosystem. Finally, a smaller but highly engaged group considers the ecosystem essential to their transformation. These firms have experienced tangible benefits from ecosystem partnerships and continue to collaborate with key actors.

SMEs' managers employ a variety of strategies to manage their I4.0 transformation, with decision-making structures playing a crucial role in shaping their approach. In most cases, the initial push for digitalisation comes from top management—either the CEO in independent SMEs or the headquarters of group-owned firms. While some leaders are introduced to the concept through industry events or media exposure, the primary driver tends to be external business imperatives such as customer expectations, competitive pressures, or broader market trends. In a minority of cases, employees propose digital solutions to improve internal processes, demonstrating a bottom-up approach to transformation.

The way SMEs' managers conceptualise their I4.0 transformation also varies. Subsidiaries of international groups tend to rely on internal resources, as strategic decisions are often guided by corporate directives. Independent SMEs, on the other hand, exhibit greater variability in their approach. Some attempt to manage transformation internally but struggle with a lack of expertise or uncertainty about where to begin. Others actively seek external support, either because they need guidance to navigate available resources or because they have a specific transformation goal but lack the technical expertise to implement it.

Few SMEs manage their I4.0 transformation solely with internal resources. Instead, most adopt a flexible and exploratory approach, engaging with external actors in various ways. Financial support plays a crucial role, since most managers aim to cut the costs of the transformation. Many managers seek technical and digital expertise by working with consultants, technology providers, and research institutions. These partnerships allow them to develop tailored digital solutions, ensuring their transformation efforts align with their operational needs. Others take a more holistic approach by rethinking organisational structures and processes, often with the support of transformation-focused consultancies or regional programs. Some firms prioritise strategic networking and knowledge exchange, engaging with industry clusters, federations, and certification programmes. These interactions serve not only as a source of information but also as a means of fostering innovation.

To conclude, rather than following a linear or predefined path, SMEs' managers navigate transformation by combining different approaches and adapting them to their specific needs. This underscores the complexity of I4.0 implementation and the diverse ways in which SMEs engage with their innovation ecosystem.

Future Research Development

To advance the analysis, the next stage of the study will aim to construct an original typology of support, based on how managers describe the nature and goals of assistance available within the innovation ecosystem. This typology will emerge inductively from the data and include quotes from interviewees to illustrate their diverse perceptions, allowing a more structured and nuanced understanding of how they make sense of the ecosystem (Weick, 1995). Building on this, the analysis will explore how managers engage with these types of support through tactics to capture differences in how these are operationalised in specific circumstances and strategic orientations (Oliver, 1991). Together, these analyses will provide insight into how SMEs' managers strategically navigate the ecosystem to manage I4.0 transformation.

These findings aim to contribute at multiple levels. Theoretically, they will offer a conceptual framework for understanding the perceptions and strategic responses of SMEs' managers to I4.0 innovation ecosystems, complementing existing studies on managing transformation. From a managerial perspective, they will provide analytical tools that managers can use to better structure and support their digital transition. At the policymaking level, the study will highlight the specific barriers SMEs face in engaging with the ecosystem and provide recommendations on refining support mechanisms to better address SMEs' needs in the context of I4.0 transformation.

Reference List

- Balogun, J., Bartunek, J.M., Do, B., 2015. Senior Managers' Sensemaking and Responses to Strategic Change. *Organization Science* 26, 960–979. <https://doi.org/10.1287/orsc.2015.0985>
- Benitez, G.B., Ayala, N.F., Frank, A.G., 2020. Industry 4.0 innovation ecosystems: An evolutionary perspective on value cocreation. *International Journal of Production Economics* 228, 107735. <https://doi.org/10.1016/j.ijpe.2020.107735>
- Castelo-Branco, I., Amaro-Henriques, M., Cruz-Jesus, F., Oliveira, T., 2023. Assessing the Industry 4.0 European divide through the country/industry dichotomy. *Computers & Industrial Engineering* 176, 108925. <https://doi.org/10.1016/j.cie.2022.108925>
- Cugno, M., Castagnoli, R., Büchi, G., 2021. Openness to Industry 4.0 and performance: The impact of barriers and incentives. *Technological Forecasting and Social Change* 168, 120756. <https://doi.org/10.1016/j.techfore.2021.120756>
- DeKrey, S.J., Portugal, E.J., 2014. Strategic Sensemaking: Challenges Faced by a New Leader of an SME. *Procedia - Social and Behavioral Sciences* 150, 56–65. <https://doi.org/10.1016/j.sbspro.2014.09.007>
- DiMaggio, P.J., Powell, W.W., 1983. The Iron Cage Revisited: Institutional isomorphism and collective rationality. *American Sociological Review* 48, 147–160.
- Fogaça, D.R., Grijalvo, M., Sacomano Neto, M., 2025. What Are Industry 4.0 and Industry 5.0 All About? An Integrative Institutional Model for the New Industrial Paradigms. *Administrative Sciences* 15, 118. <https://doi.org/10.3390/admsci15040118>
- Horváth, D., Szabo, R.Zs., 2019. Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change* 146, 119–132. <https://doi.org/10.1016/j.techfore.2019.05.021>
- Ietto, B., Ancillai, C., Sabatini, A., Carayannis, E.G., Gregori, G.L., 2024. The Role of External Actors in SMEs' Human-Centered Industry 4.0 Adoption: An Empirical Perspective on Italian Competence Centers. *IEEE Trans. Eng. Manage.* 71, 1057–1072. <https://doi.org/10.1109/TEM.2022.3144881>
- Mittal, S., Khan, M.A., Purohit, J.K., Menon, K., Romero, D., Wuest, T., 2020. A smart manufacturing adoption framework for SMEs. *International Journal of Production Research* 58, 1555–1573. <https://doi.org/10.1080/00207543.2019.1661540>
- Oliver, C., 1991. Strategic Responses to Institutional Processes. *The Academy of Management Review* 16, 145–179.
- Pfeiffer, S., 2017. The Vision of “Industrie 4.0” in the Making—a Case of Future Told, Tamed, and Traded. *Nanoethics* 11, 107–121. <https://doi.org/10.1007/s11569-016-0280-3>
- Reischauer, G., 2018. Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing. *Technological Forecasting and Social Change* 132, 26–33. <https://doi.org/Fogaça>
- Ricci, R., Battaglia, D., Neirotti, P., 2021. External knowledge search, opportunity recognition and industry 4.0 adoption in SMEs. *International Journal of Production Economics* 240. <https://doi.org/10.1016/j.ijpe.2021.108234>
- Saldaña, J., 2016. *The coding manual for qualitative researchers*, 3E [Third edition]. ed. SAGE, Los Angeles ; London.
- Santos, B., Dieste, M., Orzes, G., Charrua-Santos, F., 2022. Resources and capabilities for Industry 4.0 implementation: evidence from proactive Portuguese SMEs. *JMTM*. <https://doi.org/10.1108/JMTM-02-2022-0074>

- Scott, W.R., 2014. Institutions and organizations: ideas, interests, and identities, 4th ed. SAGE Publications.
- Somohano-Rodríguez, F.M., Madrid-Guijarro, A., López-Fernández, J.M., 2022. Does Industry 4.0 really matter for SME innovation? *Journal of Small Business Management* 60, 1001–1028. <https://doi.org/10.1080/00472778.2020.1780728>
- Sony, M., Antony, J., Tortorella, G., McDermott, O., Gutierrez, L., 2024. Determining the Critical Failure Factors for Industry 4.0: An Exploratory Sequential Mixed Method Study. *IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT* 71.
- SPW, Agence du Numérique, 2021. INDUSTRIE 4.0: ÉCOSYSTÈME WALLON DE L'ACCOMPAGNEMENT ET DE LA FORMATION.
- Teixeira, J.E., Tavares-Lehmann, A.T.C.P., 2022. Industry 4.0 in the European union: Policies and national strategies. *Technological Forecasting and Social Change* 180, 121664. <https://doi.org/10.1016/j.techfore.2022.121664>
- Vereycken, Y., Guisset, A., Ramioul, M., 2024. The same but different: Understanding variation and similarity in the outcomes of a similar technology. A comparative case study on the deployment of manufacturing execution systems in three Belgian SME's. *Information and Organization* 34, 100539. <https://doi.org/10.1016/j.infoandorg.2024.100539>
- Weick, E.K., 1995. Sensemaking in Organizations. SAGE Publications.