Empowering Entrepreneurship through High-growth Firms: Insights from a Decade-long Bibliometric Analysis

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Abstract

In Italy, the debate on industrial development and economic growth incentives highlights several key themes. Family capitalism celebrated for its resilience, is simultaneously critiqued for curbing innovation and growth potential (Colli *et al.*, 2003; González *et al.*, 2012; Yanagisako, 2020); Medium-Sized Enterprises stand out for their competitiveness, yet their representation – only 0.5% of firms – limits their macroeconomic impact (OECD, 2012). Mean-while, innovation, a cornerstone of sustainable growth, remains stifled by insufficient entrepreneurial support and inadequate public incentives. Finally, capital shortages perpetuate a systemic barrier to industrial expansion, further constraining the nation's economic trajectory. Within this environment, High-Growth Firms (HGFs), or "Gazelles," exhibit exceptional competitiveness despite comprising just 0.2% of manufacturing and 0.4% of service firms in Italy. Defined as firms with over 10 employees and annual employment growth exceeding 20% for three consecutive years, HGFs have been extensively studied (Birch, 1981; Henrekson and Johansson, 2010) yet key growth drivers and the role of innovation ecosystems remain underexplored. To address this, a

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bibliometric analysis of 2012-2021 publications identified 283 highly cited articles, segmented into pre- and post-Industry 4.0/Horizon 2020 periods. Findings highlight three drivers of HGF competitiveness: technology investment for productivity, knowledge networks via open innovation, reskilling initiatives for human capital. Industry 4.0 technologies have expanded expertise access, reduced market entry barriers, and emphasized circular economy practices, fostering ambidextrous growth. To sustain HGFs, industrial policies must adapt and expand to meet innovation demands, leveraging these insights to replicate success across evolving economic landscapes.

Keywords: High-Growth Firms (HGFs), Industry 4.0, Knowledge networks, Open innovation, Human capital.

High Growth Firm e sviluppo imprenditoriale: temi emergenti

Sommario

In Italia, il dibattito sullo sviluppo industriale e sullo sviluppo degli incentivi alla crescita economica ha nel tempo messo in luce diversi temi chiave. Il capi-talismo familiare, celebrato per la sua resilienza, è al contempo criticato per il suo effetto limitante sull'innovazione e sul potenziale di crescita (Colli *et al.*, 2003; González *et al.*, 2012; Yanagisako, 2020). Le medie imprese, pur distinguendosi per la loro competitività, rappresentano solo lo 0,5% delle aziende, riducendo così il loro impatto macroeconomico (OECD, 2012). Nel frattempo, l'innovazione, una pietra angolare della crescita sostenibile, continua a essere ostacolata da un insufficiente supporto allo sviluppo di iniziative imprenditoriali e da incentivi pubblici inadeguati. Da ultimo, le carenze di capitale rappresentano una barriera sistemica all'espansione industriale, limitando ulteriormente la traiettoria economica del Paese. In questo contesto, le High-Growth Firms (HGF), o "Gazelle", mostrano un'eccezionale competitività nonostante costituiscano appena lo 0,2% delle imprese manifatturiere e lo 0,4% di quelle nei servizi in Italia. Definite come imprese con oltre 10 dipendenti e una crescita annua dell'occupazione superiore al 20% per tre anni consecutivi, le HGFs sono state ampia-mente studiate (Birch, 1981; Henrekson e Johansson, 2010); tuttavia, i principali fattori di crescita e il ruolo degli ecosistemi dell'innovazione nel sostenerne sviluppo e crescita rimangono poco esplorati. Per affrontare questa lacuna, un'analisi bibliometrica sulla principale letteratura scientifica del periodo 2012–2021 ha identificato 283 articoli altamente citati, suddivisi tra i periodi pre- e post-Industria 4.0/Horizon 2020. I risultati evidenziano tre fattori trainanti della competitività delle HGF: investimenti tecnologici per la produttività, reti di conoscenza sostenute dalla diffusione dell'open innovation, iniziative di riqualificazione del capitale umano. Le tecnologie dell'Industria 4.0 hanno ampliato l'accesso all'expertise, ridotto le barriere all'ingresso nei mercati e dato enfasi alle pratiche di economia circolare, promuovendo una crescita ambidestra. Per sostenere le HGFs, le politiche industriali devono adattarsi ed espandersi per rispondere alle esigenze

dell'innovazione, sfruttando questi approfondimenti per replicare il successo in contesti economici in evoluzione.

Parole chiave: High-Growth Firms (HGFs), Industry 4.0, Knowledge networks, Open innovation, Human capital.

1. Introduction and Background

The rise of Industry 4.0 – characterized by technologies like Internet of Thing (IoT), Artificial Intelligence (AI), and big data – has raised the interest of researchers on business and innovation models and also on firm performance (Passarelli *et al.,* 2019; Cariola and Passarelli 2020; De Giovanni and Cariola 2021). In this context, High Growth Firms (HGFs) or "Gazelles" started to play a pivotal role in job creation, innovation, and economic dynamism, despite being relatively rare. HGFs are a small but significant group of businesses with annual growth rates of 20% or more in employment or revenue over three consecutive years (Birch 1981).

In the last years, several researchers, have proposed literature as well as empirical studies, to explore the characteristics of HGFs (Martínez-Fierro *et al.,* 2019; Rocha and Ferreira 2021). However, several gaps remain in understanding the determinants of growth in the context of Industry 4.0. While previous studies have explored the role of innovation ecosystems (Martínez-Fierro *et al.,* 2019), firm capabilities (Rocha and Ferreira 2021), and policy frameworks (Horbach, 2008), a comprehensive assessment of how Industry 4.0 technologies influence the scalability and strategic positioning of HGFs is still missing. Additionally, the interplay between digital transformation and firm-level absorptive capacity remains underexplored, requiring further empirical validation. Thus, the present study proposes a bibliometric analysis to map the evolution of HGF research, particularly before and after the widespread adoption of Industry 4.0 (2016). This analysis helps identify the dominant themes, the main changes before and after the introduction of industry 4.0, offering new insights and future perspectives.

The paper is structured as follows: the first section provides an introduction to the research topic, outlining its relevance and objectives. The second section presents a comprehensive review of the literature, establishing the theoretical framework and key concepts. The third section details the research methodology, including data collection and analysis techniques. The fourth section discusses the results, highlighting key findings and their implications. Finally, the paper concludes with a summary of insights, contributions to the field, and potential directions for future research.

2. HGF and Industry 4.0: Background

One interesting view over HGF derive from the diffusion of the concept of industry 4.0. Introduced for the first time in 2011 during the Hannover Fair in Germany, this concept represents a transformative phase in industrial and manufacturing systems, characterized by the integration of digital and cyber-physical technologies within production processes and supply chains (Meindl *et al.,* 2021). At its core, Industry 4.0 relies on foundational technologies such as the Internet of Things (IoT), cloud computing, big data, and artificial intelligence to create intelligent production systems. The evolution of Industry 4.0 has been closely linked to the rise of four key dimensions: smart manufacturing, smart supply chain, smart products and services, and smart working, which reflect the increasing interconnectedness of various industrial functions and the shift toward fully integrated and adaptable manufacturing systems. Over the past decade, research in this field has significantly contributed to increase the degree of efficiency and effectiveness of the frame. One of our hypotheses is that the spread of Industry 4.0-related literature has significantly reshaped the concept of HGF, deeply influencing its defining dimensions. We specifically anticipate that the networks influencing and defining the concept of High-Growth Firms (HGF) have undergone significant transformations in the periods before and after the widespread adoption of Industry 4.0. These changes likely reflect shifts in technological paradigms, business models, and innovation ecosystems, which have restructured the way firms scale, collaborate, and compete in an increasingly digital and automated industrial landscape. For this reason, considering that the first government incentives related to industry 4.0 were formally introduced starting in 2011 – with a concrete launch marked by the Advanced Manufacturing Partnership in the USA – we have chosen 2016 as the cut off year for the pre-Industry 4.0 phase. The selection of 2016 as the cut off year for distinguishing pre- and post-Industry 4.0 is pivotal yet requires explicit justification. The year 2016 marked a critical turning point in global industrial dynamics, coinciding with the Fourth Industrial Revolution gaining widespread recognition. The World Economic Forum's annual meeting in Davos in 2016 cantered on Industry 4.0 technologies such as artificial intelligence, robotics, and the Internet of Things (IoT), emphasizing their transformative potential across sectors (Schwab 2016). Furthermore, several nations, including Germany, the United States, and China, launched strategic initiatives to integrate these technologies into their manufacturing sectors, symbolizing a global commitment to this industrial paradigm. By aligning the analysis to this milestone, the study ensures temporal relevance and contextual accuracy in understanding the evolving role of High-Growth Firms (HGFs).

3. Methodology

We adopted recent methodologies in bibliometric research (Ferreira and Serpa 2018; Caputo *et al.,* 2021) using a systematic review protocol for data collection (Wright *et al.,* 2007). The search, selection, and analysis of articles followed a structured procedure designed to identify the most relevant studies (Tranfield *et al.,* 2003; Denyer and Tranfield 2009). Throughout the process, we adhered to principles of equality, focus, accessibility, and transparency in handling the identified items (Thorpe *et al.,* 2005). Bibliometric-based citation analysis provides a powerful framework for mapping the intellectual structure and thematic progression of high-growth firm (HGF) research. This approach uses bibliometric data to visualize the state of art of the field and possible future researchers. Specifically, we retrieved bibliographic data from the Web of Science database using an extensive Boolean search including terms related to HGF, such as "Firm growth determinants", "Firm growth antecedents", "High-growth firms", "Innovation ecosystem", "Driver of innov*", "Driver of dynamic sectors", "Innovative firms" and "Gazelles firms". We included 283 articles from 2012 to 2021. We used R Bibliometrix syntax for the bibliometrix analysis.

Grounding on Aria and Cuccurullo (2017) definition of co-citation, we have investigated the intellectual framework in order understand how an author's work influences the scientific community using co-citation analysis (Kessler 1963), which examines whether two works are jointly cited by a third work. Over time, co-citation analysis can help identify changes in paradigms and schools of thought.

4. Main Findings

The analysis has been carried out across two distinct research trajectories in High-Growth Firms (HGF) studies, delineating the pre-Industry 4.0 period (before 2016) and the post-Industry 4.0 period (from 2016 onward). This segmentation allows for a comparative examination of how Industry 4.0 has influenced the evolution, dynamics, and strategic behavior of HGFs, highlighting key shifts in innovation, technology adoption, and market positioning between the two phases (Liao *et al.,* 2017; Dalenogare *et al.,* 2018).

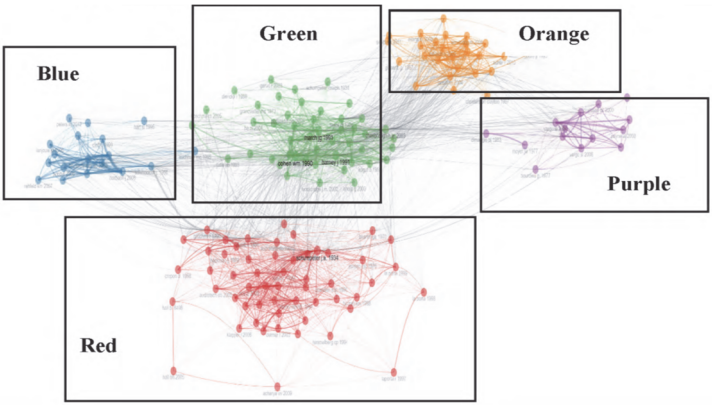
4.1 The phase Pre industry 4.0

We performed a co-citation analysis on the most highly cited articles to identify the most influential authors and the trajectories of research within the field. This analysis uncovered a complex intellectual structure, delineating five distinct clusters that form the foundation of the field's theoretical and empirical framework. Table 2 provides a detailed breakdown of the articles categorized by cluster, while Figure 1 offers a graphical representation of the clusters, illustrating their interconnections and thematic focus.

Table 1 – Clusters detail of co-citation for pre industry 4.0

Cluster	Reference
1	Schumpeter J.A. 1934, Acs Z.J. 1990, Griliches Z 1990, Pavitt K 1984, Schumpeter J.A. 2003, Acs Zj 2008, Audretsch Db 1996, Audretsch Db 2005, Griliches Z 1979, Storey Davidj. 1994, Aghion P 1992, Coad A 2008, Heckman Jj 1979, Lucas Re 1988, Acs Zj 1988, Crepon B. 1998, Dosi G 1988, Fazzari Sm 1988, Hall B. 8498, Hall Bh 2002, Holzl W 2009, Jaffe Ab 1986, Jaffe Ab 1989, Jensen Mc 1976, La Porta 1999, Shane S 2009, Acharya Vv 2009, Acs Zj 2002, Acs Zj 2009, Akerlof Ga 1970, Arrow K. 1962, Audretsch D. 2006, Bushee Bj 1998, Chandler A.D. 1990, Colombo Mg 2005, Delmar F 2003, Geroski Pa 1995, Greene W.H. 2003, Hall Bh 2005, Henrekson M 2010, Himmelberg Cp 1994, Kirzner Im 1997, Klapper L 2006, La Porta 1998, Laporta R 1997, Malerba F 1995, Miller D. 2005, Nelson Rr 1959, Rajan Rg 1998, Romer Pm 1986, Romer Pm 1990, Santarelli E 2007, Saxenian A. 1994, Schneider C 2010, Shane S 2000
2	Horbach J 2008, Porter Me 1995, Rennings K 2000, Brunnermeier Sb 2003, Hart Sl 1995, Schmookler J. 1966, Jaffe Ab 1997, Suchman Mc 1995, Cleff T. 1999, Jaffe Ab 2002, Popp D 2006, Gonzalez Pd 2009, Horbach J 2012, Jaffe Ab 1995, Lanjouw Jo 1996, Lanoie P 2011, Peters M 2012, Rehfeld Km 2007
3	Cohen Wm 1990, Barney J 1991, March Jg 1991, Henderson Rm 1990, Nelson R.R. 1982, Dosi G 1982, Katila R 2002, Laursen K 2006, Chesbrough H.W. 2003, Teece Dj 1986, Powell Ww 1996, Eisenhardt Km 1989, Kogut B 1992, Podsakoff Pm 2003, Tushman Ml 1986, Cassiman B 2006, Eisenhardt Km 2000, Jaffe Ab 1993, Leonardbarton D 1992, Levinthal Da 1993, Teece Dj 1997, Wooldridge J.M. 2002, Chesbrough H. 2006, Cyert R.M. 1963, Dahlander L 2010, Eisenhardt Km 2007, Hargadon A 1997, Rosenkopf L 2001, Von Hippel 1988, Von Hippel 2005, Wernerfelt B 1984, Ahuja G 2000, Bathelt H 2004, Boschma Ra 2005, Chesbrough H.W. 2006, Dierickx I 1989, Fleming L 2001, Garud R 2003, Granovetter Ms 1973, He Zl 2004, Leiponen A 2010, Lundvall B.A. 1992, Nelson R.R. 1993, Ocasio W 1997, Ocasio W 2011, Schumpeter Joseph 1934, Shan Wj 1994
4	Vargo Sl 2004, Dimaggio Pj 1983, Payne Af 2008, Vargo Sl 2008, Vargo Sl 2011, Vargo Stephen 2008, Bourdieu P. 1977, Chandler Jd 2011, Edvardsson B 2011, Giddens A. 1986, Mccoll-Kennedy Jr 2012, Meyer Jw 1977, Prahalad Ck 2000, Simon H. 1996
5	Iansiti M. 2004, Boudreau Kj 2012, Rochet Jc 2003, Adner R 2010, Caillaud B 2003, Christensen Cm 1995, Eisenmann T 2006, Gawer A. 2002, Smith Wk 2011, Tiwana A 2010, Armstrong M 2006, Baldwin C.Y. 2000, Boudreau K 2010, Boudreau Kj. 2009, Ceccagnoli M 2012, Christensen Clayton 1997, Dhanaraj C 2006, Eisenmann T 2011, Evans D. 2006, Gawer A 2007, Gawer A 2008, Glaser B.G. 1967, Jacobides Mg 2006, Moore Jf 1993, Parker Gg 2005, Stinchcombe A.L. 1965

Figure 1 – Large component of the citation network in the pre industry 4.0 phase



- *The first cluster (Red)* focuses on the economic foundations of innovation, anchored by Schumpeter's (1934) theory of creative destruction; it reminds also Griliches' (1979) insights on R&D spillovers, highlighting the pivotal role of innovation in driving economic growth. These perceptions are particularly relevant to explore the dynamic evolution of High-Growth Firms (HGFs), as the disruptive power of innovation is often the engine behind their rapid scaling and economic impact. HGFs leverage R&D spillovers and capitalize on innovation-driven opportunities to establish competitive dominance in their industries.
- *The second cluster (Green)* delves into organizational and strategic dimensions, emphasizing absorptive capacity (Cohen and Levinthal 1990), resource-based views (Barney 1991) and the balance between exploration and exploitation (March 1991) as critical enablers of competitive advantage. For HGFs, these theories are essential: absorptive capacity enables these firms to rapidly assimilate and apply external knowledge, while the resource-based view underscores the importance of leveraging unique internal assets to sustain growth. Furthermore, their ability to balance exploration (innovation) and exploitation (efficiency) is a hallmark of their adaptability and success in volatile markets.
- *The blue cluster* delves into the role of institutional and policy frameworks, with key contributions such as DiMaggio and Powell's (1983) institutional isomorphism and Porter's (1995) hypothesis linking regulation to competitive advantage. HGFs, operating in dynamic and often regulated environments, exemplify how firms can use institutional and regulatory pressures as drivers for innovation. For example, the Porter hypothesis suggests that well-designed environmental regulations can spur

innovation, a strategy often observed in HGFs that lead in green technologies or eco-innovation.

- *The orange cluster* centres on the dynamics of networks and ecosystems, featuring Chesbrough's (2003) open innovation and Powell's (1996) insights into inter-organizational collaborations. HGFs thrive in networked ecosystems, using partnerships, alliances, and collaborations to access resources, expand their market reach, and accelerate innovation. Open innovation practices allow these firms to integrate external ideas and technologies, creating a virtuous cycle of growth and innovation.
- *Finally, the purple cluster* highlights the intersection of environmental sustainability and technological change, drawing on works like Horbach's (2008) analysis of environmental innovation and Schmookler's (1966) demand-pull theory. These insights align with the strategies of HGFs in industries where environmental concerns and technological advancements converge. Such firms often lead in developing environmentally sustainable innovations that address market demands while also driving competitive advantage and long-term growth.

4.2 Findings: Post-Industry 4.0 (2016-2021)

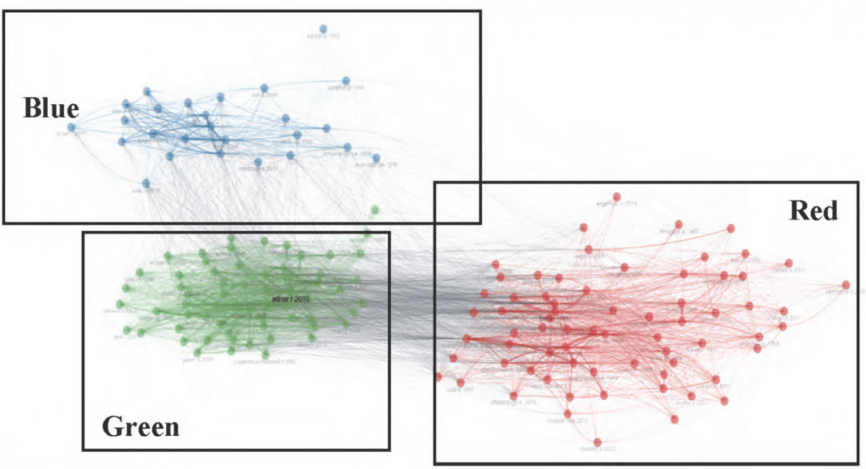
As for the pre-Industry 4.0 period, from the co-citation analysis, we immediately observed a notable shift toward a reduced number of clusters, reflecting an evolution characterized by increased specificity and a more focused exploration of key themes. This narrowing of thematic scope is accompanied by a parallel refinement of the theoretical paradigms that underpin these works, signing a trend toward greater conceptual clarity and practical application in the theories developed during this period.

Table 2 – Clusters detail of co-citation for post industry 4.0

Cluster	Reference
1	Barney J 1991, Teece Dj 1997, Cohen Wm 1990, Laursen K 2006, Chesbrough H.W. 2003, Fornell C 1981, Podsakoff Pm 2003, Dahlander L 2010, Nelson R.R. 1982, Eisenhardt Km 1989, Eisenhardt Km 2000, Vargo Sl 2004, March Jg 1991, Wernerfelt B 1984, Chesbrough H.W. 2006-1, Grant Rm 1996, Hart Sl 1995, Katila R 2002, Dyer Jh 1998, Penrose E.T. 1959, Teece Dj 2010, Boons F 2013, Chesbrough H. 2006, Dosi G 1982, Eisenhardt Km 2007, Gioia Da 2013, Osterwalder A. 2010, Strauss A. 1998, Tranfield D 2003, West J 2014-1, Anderson Jc 1988, Chen Ys 2006, Crossan Mm 2010, Del Giudice 2014, Granovetter Ms 1973, Huizingh Ekre 2011, Nonaka I 1994, Nonaka I. 1995, Ocasio W 1997, Tushman Ml 1996, Van De 2009, West J 2014-2, Alavi M 2001, Armstrong Js 1977, Bansal P 2000, Carrillo-Hermosilla J 2010, Cyert R.M. 1963, Dimaggio Pj 1983, Hair J.F. 2009, Horbach J 2008, Kammerer D 2009, Nahapiet J 1998, Payne Af 2008, Pfeffer J. 1978, Porter M. 1985, Porter Me 2014, Powell Ww 1996, Russo Mv 1997, Spender Jc 1996, Uzzi B 1997, Von Hippel 2005, Vrontis D 2017, Zahra Sa 2002, Angelidou M 2014,

	Bocken Nmp 2014, Cavusgil St 2003, Chang Ch 2011, Chesbrough H. 2014, Chesbrough H.W. 2006-2
2	Acs Zj 2014, Autio E 2014, Isenberg Dj 2010, Feld B. 2012, North Dc 1990, Schumpeter J.A. 1934, Spigel B 2017, Bathelt H 2004, Cooke P 1997, Lumpkin Gt 1996, Shane S 2000, Stam E 2015, Acs Zj 2009, Acs Zj 2017, Audretsch Db 2016, Autio E 2018, Bahrami H 1995, Delgado M 2010, Mack E 2016, Marshall A. 1920, Nambisan S 2017, Porter Me 1998, Aghion P 1992, Asheim Bt 2011, Audretsch Db 1996, Brown R 2017
3	Adner R 2010, Teece Dj 2007, Moore Jf 1993, Gawer A 2014-1, Adner R 2017, Gawer A 2014-2, Gawer A. 2002, Teece Dj 1986, Adner R 2006, Zott C 2011, Henderson Rm 1990, Yoo Yj 2010, Kapoor R 2013, Gawer A 2007, Iansiti M 2004, Jacobides Mg 2018, Lusch Rf 2015, Nambisan S 2013, Parker G.G. 2016, Rochet Jc 2003, Wareham J 2014, Cennamo C 2013, Eisenmann T 2006, Iansiti M. 2004, Autio E. 2014, Boudreau K 2010, Ceccagnoli M 2012, Clarysse B 2014, Gulati R 2012, Parker Gg 2005, Ritala P 2013, Sarasvathy Sd 2001, Tilson D 2010, Adner R 2016, Christensen Clayton 1997, Coase Rh 1937, Dhanaraj C 2006, Evans Ds. 2016, Gawer A 2008, Jacobides Mg 2006, Moore J.F. 1996, Rohrbeck R 2009, Thomas Ldw 2014, Tiwana A 2010, Van Der 2012, West J 2003, Williamson Pj 2012, Yoo Y 2012, Adner Ron. 2012, Ansari S 2016, Baldwin C.Y. 2000, Chesbrough H 2014, Hagiu A 2015, Kapoor R 2015, Katz Ml 1985, Nelson R.R. 1993, Santos Fm 2009, Vargo Sl 2015, Alexy O 2013, Amit R 2001, Anderson P 1990, Armstrong M 2006, Boudreau Kj 2012, Caillaud B 2003, Casadesus-Masanell R 2007

Figure 2 – Large component of the citation network in the post industry 4.0 phase



Under this perspective the co-citation analysis highlights thematic clusters that provide a nuanced perspective on the dynamic drivers of high-growth firms (HGFs) in a post-Industry 4.0 context, emphasizing innovation ecosystems, entrepreneurial frameworks, and strategic adaptability. This structure can be contrasted with the pre-Industry 4.0 framework, which emphasized foundational theories and the interplay between economic, organizational, institutional, and ecological dimensions. We found three different cluster.

- *Cluster 1 (Red): resource-based view and dynamic capabilities*: this cluster highlights the importance of internal firm competencies, particularly the resource-based view (Barney 1991) and dynamic capabilities (Teece *et al.,* 1997), as critical drivers for high-growth firms (HGFs). These firms achieve rapid scaling by leveraging unique, inimitable resources and adapting to environmental changes through dynamic capabilities. The concept of absorptive capacity (Cohen and Levinthal, 1990) further enriches this cluster by emphasizing HGFs' ability to assimilate and apply external knowledge to drive innovation. In comparison to the pre-Industry 4.0 analysis, this cluster closely aligns with the green cluster, which also focuses on absorptive capacity and resource-based views. However, the post-Industry 4.0 perspective builds on these ideas by emphasizing the role of dynamic capabilities as essential for navigating rapid technological advancements and digital transformation in this era.
- *Cluster 2 (Blue): entrepreneurial ecosystems and national systems of entrepreneurship*. This cluster examines systemic factors that shape entrepreneurial success, with a focus on the role of institutional contexts and ecosystems. Foundational works like Acs *et al.,* (2014) on national systems of entrepreneurship and Isenberg's (2010) framework for entrepreneurial ecosystems highlight the importance of supportive policies, cultural norms, and robust networks in fostering the success of high-growth firms (HGFs). The pre-Industry 4.0 blue cluster emphasized institutional and policy frameworks, drawing on concepts such as DiMaggio and Powell's (1983) institutional isomorphism and Porter's (1995) hypothesis. While both analyses acknowledge the importance of institutions, the post-Industry 4.0 framework shifts its focus to the dynamic interactions within entrepreneurial ecosystems, reflecting the growing complexity and interconnectedness of contemporary markets.
- *Cluster 3 (Green): Co-development and technological change*. This cluster examines the interdependencies and co-evolution within innovation ecosystems, with seminal contributions such as Adner and Kapoor's (2010) work on value creation in innovation ecosystems and Moore's (1993) analogy of business ecosystems. HGFs thrive in these ecosystems by leveraging technological interdependence and engaging in strategic collaborations that drive innovation. The orange cluster from the pre-industry 4.0 framework focused on networks and inter-organizational collaborations (Chesbrough, 2003).

5. Conclusion and Contribution

The evolving conceptual structure reflects the heightened complexity and interconnectedness of HGF dynamics in the Industry 4.0 era. While the pre-Industry 4.0 period laid the groundwork by emphasizing innovation ecosystems and institutional frameworks, the post-Industry 4.0 phase integrates these elements into a cohesive model that prioritizes performance, adaptability, and sustainability. This transition demonstrates how the emphasis has shifted from foundational concepts and broad institutional frameworks to more integrated and performance-oriented themes, reflecting the increasing complexity and interconnectedness of innovation systems in the Industry 4.0 era. These evolving clusters also underscore the critical role of High-Growth Firms as drivers of innovation, linking their rapid scalability to strategic use of resources, systemic support structures, and long-term market evolution. This study illuminates the transformative journey of high-growth firms (HGFs) as they navigate an increasingly complex industrial landscape. In the pre-Industry 4.0 phase, research centred on foundational strategies – value creation, resilience, and resource management – that underscore the significance of internal capabilities and adaptive strength for sustainable growth. With the onset of Industry 4.0, however, the focus shifted toward the integration of advanced technologies and external ecosystems, highlighting concepts such as absorptive capacity, co-development and eco-innovation. This shift reflects a broader redefinition of competitive advantage and firm performance, where HGFs leverage digital transformation and sustainability to remain agile and impactful. Our findings are in line with the topic addressed by Alfio Cariola in the last years. His papers focused on the co-development of innovation, on the role of open innovation in the perspective to improve firm performance. As an engineer, Alfio was always interested to the theme of new technologies. In the last years, he also focused the attention on some issues related to Industry 4.0, by producing also papers and conference contributes. He was a meticulous researcher and he liked to understand in deeply all the phenomenon; for this reason, co-citation analysis was among the literature review who preferred in the last years of his research activity. Alfio we miss you.

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