Manufacturing Innovation and the Role of Entrepreneurship

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Abstract

This review examines the pivotal role of entrepreneurship in fostering innovation within manufacturing industries. This article synthesises theoretical, empirical, and policy-oriented insights. I explore how entrepreneurial activities, whether through independent start-ups, SMEs, or intrapreneurship within established firms, act as critical catalysts for technological upgrading in manufacturing sectors. The analysis integrates innovation theory, the knowledge spillover perspective, and entrepreneurial ecosystem frameworks, while also emphasising the embedding of entrepreneurship within institutional contexts. Our findings reveal that the effectiveness of entrepreneurial-led manufacturing innovation is highly contingent on factors such as ecosystem health, networks, policy design, and cultural milieu. The review identifies key debates regarding the quality versus quantity of entrepreneurship, the optimal role of the state in ecosystem development, and contextual nuances influencing entrepreneurial outcomes. Emerging research frontiers including digital manufacturing entrepreneurship, comparative ecosystem studies, and multi-level dynamic analyses are proposed as promising avenues for future inquiry. In conclusion, the article asserts that entrepreneurship remains a linchpin of manufacturing innovation, but realising its full potential requires a nuanced orchestration of formal institutions, social capital, firm-level capabilities, and policy interventions aligned with sustainable development goals.

Keywords: Manufacturing innovation, Entrepreneurship, Entrepreneurial ecosystems, Sustainable entrepreneurship, Industry 4.0.

Introduction

Manufacturing industries have long been a cornerstone of economic development and technological progress. From the dawn of the industrial era to the present *avant-garde* digital age, innovation in manufacturing has driven productivity gains, job creation and prosperity. Yet who drives such innovation? Increasing evidence suggests that entrepreneurship – the actions of founders, small firms, and entrepreneurial managers – plays a catalysing rôle in sparking and diffusing innovation in manufacturing sectors (Autio et al., 2014; Kim & Hur, 2022). Schumpeter's classic thesis posited the entrepreneur as an agent of *créative destruction*, introducing new products and processes that render old ones obsolete and propel industrial change (Schumpeter, 1934). In the twenty-first century, this raison d'être of entrepreneurship vis-à-vis innovation appears ever more salient amidst rapid technological shifts (e.g., digital manufacturing, Industry 4.0) and pressing sustainability challenges. Entrepreneurial firms often exhibit agility and risk-taking that larger incumbents may lack, allowing them to pursue breakthrough manufacturing innovations (Cavallo et al., 2019; Khan et al., 2021a). At the same time, established manufacturing clusters and ecosystems are being reinvigorated by startup activity and corporate venture initiatives, suggesting an evolving symbiosis between new ventures and established firms in driving innovation (Bouncken & Kraus, 2021; Colombo et al., 2022).

This article provides a comprehensive literature review on *manufacturing innovation and the role of entrepreneurship*. I synthesise recent advances in research and critically examine how entrepreneurial activities – whether by independent startups, small and medium-sized enterprises (SMEs), or intrapreneurs within established firms – contribute to innovation, technological upgrading, cluster development and sustainable prosperity in manufacturing industries. Building on the recent scholarly contributions, our review analyses the mechanisms linking entrepreneurship and manufacturing innovation, debates the

contingencies and contextual factors (e.g. institutional milieu, regional clusters, sustainability imperatives), and identifies gaps and future research directions.

I proceed as follows. The next section presents the theoretical background, outlining key frameworks that explain why and how entrepreneurship may spur innovation in manufacturing – from Schumpeterian theory and the knowledge spillover view to entrepreneurial ecosystem and institutional perspectives. I then review recent advances in the literature, organising findings into themes such as entrepreneurial orientation and firm-level innovation performance, the role of entrepreneurial ecosystems and clusters in regional manufacturing innovation, the influence of social capital on industrial innovation outcomes, and the intersection of entrepreneurship with digitalisation and sustainability in manufacturing. Next, I discuss debates and gaps, examining conflicting evidence or open questions (e.g., the quality versus quantity of entrepreneurship and policy conundrums in cluster development). In future directions, I suggest promising avenues for research, including multi-level analyses linking entrepreneurs to ecosystem outcomes, the need for more evidence in emerging market manufacturing contexts, and the integration of sustainability and inclusion goals into manufacturing entrepreneurship. Finally, I conclude with reflections on the practical implications for policymakers and industry leaders seeking to leverage entrepreneurship as a lever for manufacturing innovation and sustainable prosperity.

Theoretical Background

Entrepreneurship and Innovation

The intellectual origins of linking entrepreneurship to innovation in manufacturing can be traced to Joseph Schumpeter's seminal work in the early 20th century. Schumpeter (1934) argued that the entrepreneur is the prime mover of economic development by carrying out "new combinations" – introducing new products, new production methods, opening new markets, or reorganising industries – thereby driving *innovation* and growth. In Schumpeter's view, entrepreneurial innovation is a process of *creative destruction* that continuously revolutionises the industrial structure from within, destroying the old and creating the new. This perspective casts entrepreneurs as *agents of change* who upset equilibria and challenge incumbent firms, a phenomenon particularly evident in manufacturing industries during industrial revolutions (Schumpeter, 1942). While Schumpeter's theory is well-known, it continues to underpin modern research; indeed, contemporary scholars often frame entrepreneurship as a key mechanism translating technological opportunities into realised innovation outcomes (Wurth et al., 2022; Cho et al., 2021). For manufacturing sectors, which historically were dominated by large firms and incremental innovations, the Schumpeterian lens suggests that entrepreneurial firms (startups or new market entrants) are vital for radical innovations – for example, the introduction of an entirely new manufacturing process or disruptive product architecture (Autio et al., 2014). Recent empirical evidence supports this notion: in high-technology manufacturing, new ventures have been found to drive commercialization of high-impact innovations that incumbents might overlook due to cannibalisation concerns or organisational inertia (Howell, 2022; Chandy et al., 2021). Startups arguably have greater incentive to pursue risky breakthrough R&D, whereas established firms "have more to lose" and may focus on sustaining existing competencies (Nanda et al., 2020). Thus, the Schumpeterian argument still resonates in explaining why entrepreneurial activity injects dynamism into manufacturing innovation ecosystems.

Modern extensions of Schumpeter's framework also highlight the **complementarity** between entrepreneurial and established firms in innovation systems. Rather than viewing startups and incumbents in adversarial terms only, recent studies point to collaborative relationships – such as partnerships, alliances, or acquisitions – through which entrepreneurial ventures and big manufacturers jointly contribute to innovation (Hummel et al., 2021; Doh & Acs, 2022). For instance, in complex manufacturing fields like automotive or

aerospace, startups often develop specialised novel technologies (e.g., a new battery chemistry or a software for optimising production) and then partner with large manufacturers who have the scaling capabilities to bring these innovations to mass production (Ketchen et al., 2021). An Academy of Management Journal study by *Bercovitz and Feldman (2021)* coined this the "big fish versus big pond" dynamic, illustrating that entrepreneurs can thrive by leveraging the resources of incumbent firms (the big ponds), while incumbents benefit from the entrepreneurs' innovations (the big fish) – creating mutual value in the innovation process. This nuance extends Schumpeter's idea by acknowledging that entrepreneurship's role in manufacturing innovation is not limited to direct competition; it also includes *co-innovation* and knowledge exchange within an ecosystem of diverse actors. In summary, Schumpeterian theory and its evolutions provide a foundational understanding that entrepreneurship – in all its forms – is a critical driver of innovation and renewal in manufacturing industries, whether through disruption or cooperation.

Knowledge Spillovers, Clusters and Entrepreneurial Ecosystems

While Schumpeter focused on the individual entrepreneur, later theoretical work emphasised the context in which entrepreneurship and innovation occur. A prominent framework here is the Knowledge Spillover Theory of Entrepreneurship (KSTE) (Acs et al., 2009; Audretsch & Keilbach, 2007). KSTE posits that investments in knowledge creation (R&D, new technologies, skilled human capital) do not automatically translate into commercial innovation – there often exists a gap between knowledge generation and its application. Entrepreneurship is seen as the conduit that allows knowledge "spilled" from incumbents, universities or labs to be picked up and turned into innovative products or firms (Acs et al., 2013). In a manufacturing context, this means entrepreneurial startups often emerge in proximity to knowledge sources like research centres or large plants, and they exploit knowledge spillovers to introduce innovations that the original knowledge producers might not pursue. For example, a new materials breakthrough made in a university may be commercialised by a spin-off venture that develops a novel manufacturing process for that material (Audretsch et al., 2021). This helps explain why manufacturing innovation tends to concentrate in clusters – geographic concentrations of interconnected firms, suppliers, and knowledge institutions. Within clusters (e.g., Silicon Valley for electronics, Germany's Baden-Württemberg for automotive engineering, or Shenzhen for electronics manufacturing), dense networks facilitate the flow of ideas and skills, and entrepreneurs are quicker to spot and seize opportunities from these flows (Delgado et al., 2016; Breznitz & Taylor, 2022). Empirical studies show that regions with stronger knowledge spillover dynamics exhibit higher rates of new firm formation and faster diffusion of manufacturing innovations (Ghio et al., 2019; Audretsch et al., 2021). Startups in such clusters often serve as a mechanism to transfer and recombine knowledge from established firms or research institutions into innovative outputs, thereby enhancing the overall innovative performance of the cluster (Qian, 2018). This aligns with Porter's (1990) notion that clusters create a fertile *milieu* for innovation through intense interactions and competition, updated in recent work to include startup-driven knowledge circulation (Delgado, 2020).

The cluster concept has evolved into the broader idea of entrepreneurial ecosystems. An entrepreneurial ecosystem refers to the constellation of interdependent actors (entrepreneurs, firms, universities, investors, government agencies, etc.) and factors (culture, policies, support services, markets) that collectively support productive entrepreneurship in a region or industry (Stam, 2015; Isenberg, 2010). In the context of manufacturing, an ecosystem perspective extends beyond spatial clustering to incorporate functional pillars like financing, human capital, mentorship networks, and institutional supports that enable new ventures to form and scale (Spigel, 2017). Crucially, entrepreneurial ecosystems are now recognised as a key determinant of innovation outcomes. Stam and van de Ven (2021) identify a set of *entrepreneurial ecosystem elements* – including formal institutions, culture, networks, physical infrastructure, demand, leadership, talent, finance, and knowledge – that together create an environment where entrepreneurs can thrive and innovate. Their research in *Small Business Economics* finds that regions scoring highly on these ecosystem

elements tend to have greater entrepreneurial activity and innovation performance (Stam & van de Ven, 2021). Similarly, Leendertse et al. (2022) propose robust metrics for ecosystem health (e.g. connectivity between actors, resource availability) and demonstrate in a cross-country analysis that well-developed entrepreneurial ecosystems correlate with higher innovative start-up rates and patenting outputs, especially in technology-intensive manufacturing sectors. This systemic view echoes the earlier cluster literature but puts greater emphasis on *interdependencies and governance* – for instance, how the presence of research universities (producing knowledge and talent) combined with accessible venture capital and supportive industrial policies can significantly boost innovative entrepreneurship (Cao & Shi, 2020; Autio et al., 2018).

One of the most compelling illustrations of ecosystem effects is found in the policy-driven development of advanced manufacturing clusters. Xu and Hu (2024), in a recent study of Jiangsu Province in China, analysed a series of regional industrial policies aimed at creating "world-class advanced manufacturing clusters" in industries like new materials, robotics, and biotechnology. Through mixed-method analysis (text mining of 52 policy documents and a Policy Modelling Consistency index), they found that Jiangsu's government has acted as a *"facilitating state"* – aligning policy instruments with high-quality development goals and providing consistent support to cluster initiatives. In other words, effective policy can encourage entrepreneurs to start new ventures within the cluster or collaborate on innovation projects, thus invigorating the ecosystem. Their findings underscore that a well-designed entrepreneurial ecosystem – in this case, deliberately cultivated by regional authorities – can be a powerful engine for sustainable innovation in manufacturing. This aligns with the broader evidence that ecosystems with supportive institutions and policies tend to generate more productive entrepreneurial activities (Audretsch & Belitski, 2017; Acs et al., 2014). However, it also introduces a note of debate: how far should governments go in orchestrating ecosystems? I will return to this question in our discussion of policy and cluster development debates. For now, the theoretical point is that vibrant entrepreneurial ecosystems, whether organically evolved or policy-boosted, provide fertile ground for manufacturing innovation by combining knowledge spillovers, resource flows, and network dynamics that empower entrepreneurs (Chaudhary et al., 2024).

Entrepreneurial Orientation and Firm Innovation

At the firm level, scholars have examined how the entrepreneurial orientation (EO) of a manufacturing enterprise influences its innovation outcomes. Entrepreneurial orientation is a strategic posture encompassing dimensions such as proactiveness, innovativeness, and risk-taking (Miller, 1983; Covin & Slevin, 1989). Firms with a high EO are predisposed to seek novel opportunities, experiment with new ideas, and venture into uncertain markets – behaviours that naturally link to innovation production. A number of recent studies confirm that EO is positively associated with innovation performance in manufacturing SMEs (e.g., new product introductions, patent counts, process improvements), though with some nuanced findings. For instance, Boso et al. (2013) had earlier found EO boosted product innovation in emerging economy firms, and newer evidence reinforces this across contexts. Kim and Hur (2022) provide a fine-grained analysis in a sample of South Korean manufacturing SMEs: they show that an entrepreneurial orientation drives more radical forms of innovation (specifically, "new-to-the-industry" product and process innovations). In contrast, a strong market orientation (MO) – a focus on customers and competitors – tends to drive more incremental innovation ("new-to-the-firm" improvements) (Kim & Hur, 2022). Intriguingly, their study finds that when a firm tries to pursue both orientations simultaneously, the conflicting strategic logics can dampen overall innovation performance. This suggests that manufacturing firms may face an orientation trade-off: an EO pushes the frontier of technology and yields breakthrough innovations, but balancing it with a customer-centric MO may be challenging without organisational ambidexterity. The implication is that entrepreneurial orientation is a key internal driver of innovation, especially disruptive innovation, but it requires alignment in the firm's strategy. Other scholars have echoed that a proactive entrepreneurial strategy, coupled with capabilities like absorptive capacity and open innovation practices,

significantly enhances innovation outcomes (Brettel & Cleven, 2019; Nsanzurwimo et al., 2022). There is also evidence that EO's effect on innovation can be amplified or mediated by other factors – for example, strategic human resource management and a culture of learning can channel EO into higher innovation productivity (Xie et al., 2022; Janošková et al., 2021).

Within large, established manufacturing companies, the analogous concept is corporate entrepreneurship or intrapreneurship – essentially fostering EO at the business-unit or employee level. Corporate entrepreneurship includes activities like internal startups, skunkworks projects, and employee-driven innovations (Zahra, 1991; Kuratko et al., 2021). Recent research indicates that corporate entrepreneurship positively correlates with firm innovation performance in manufacturing. For example, an empirical study by Anagnostopoulos et al. (2021) found that manufacturing firms with formal programs to encourage intrapreneurial projects saw significant increases in patent outputs and radical innovation success compared to those without such programs. This is consistent with a meta-analysis by Phan et al. (2022) that concluded corporate entrepreneurship has a significant positive effect on overall firm innovativeness and growth. The takeaway is that an entrepreneurial mindset, whether in a startup or an incumbent firm, is conducive to innovation. However, harnessing this within larger organisations often requires structural and cultural support (e.g., autonomous venture units, reward systems for innovation) to overcome bureaucratic inertia (Hornsby et al., 2013; Shanker et al., 2021).

In summary, from a theoretical standpoint, firms that exhibit strong entrepreneurial orientation and behaviour tend to be more innovative. Entrepreneurship provides the *organisational impetus* for exploring new technologies and business models in manufacturing, going beyond routine R&D. The literature therefore positions EO as both a trait of new ventures (distinguishing high-growth innovative startups from lifestyle firms) and a strategique choice for established firms aiming to remain competitive through innovation. The concept links individual-level entrepreneurial action with firm-level innovation outcomes, complementing the ecosystem view discussed earlier. Combined, I see a multi-level theoretical picture: entrepreneurial *actors* (individuals, firms) with certain orientations drive innovation, and supportive *structures* (knowledge networks, ecosystems, institutions) enable and amplify this process. I will next delve into the latest empirical findings that flesh out these theoretical linkages in practice, focusing on studies from 2020 onwards.

Recent Advances in Research

Entrepreneurial Ecosystems, Clusters and Innovation Outcomes

Research since 2020 has significantly advanced our understanding of how entrepreneurial ecosystems and clusters contribute to manufacturing innovation. One notable development is the increasing body of systematic literature reviews and conceptual papers that attempt to synthesise the ecosystem–innovation nexus. For example, Chaudhary et al. (2024) conducted a review of 98 studies on entrepreneurial ecosystems and innovation, revealing that scholars coalesce around three predominant themes: (1) the pivotal role of universities and research institutions in ecosystems, (2) the role of entrepreneurial actors (startups, scale-ups) themselves, and (3) viewing innovation as an outcome of well-functioning ecosystems. Their analysis highlights that interactions between various ecosystem elements – such as academic institutions providing knowledge, entrepreneurs exploiting that knowledge, and intermediaries (incubators, accelerators) facilitating connections – are crucial for generating innovation in a region. Notably, Chaudhary et al. (2024) stress the "crucial role of entrepreneurial actors as drivers of innovation" within these systems, reaffirming that without the initiative of entrepreneurs, the latent potential of ecosystems may not translate into realised innovation outcomes.

Empirical studies at the regional level support this view. In China, Xie et al. (2021) took a configurational approach to examine how different factors of city-level entrepreneurial ecosystems combine to affect the quantity and quality of regional entrepreneurship. Using data from Chinese cities, they found multiple "paths" to high entrepreneurial outcomes – for instance, one configuration showed that strong formal institutions *and* cultural support for entrepreneurship together yielded not just more startups (quantity) but also higher rates of patenting per startup (quality), indicative of more innovative entrepreneurship (Xie et al., 2021). In these high-performing configurations, manufacturing clusters were often present, suggesting that industrial specialisation plus a healthy ecosystem (with access to talent, capital, etc.) produced the best innovation results. Complementing this, Ding et al. (2023) looked at Chinese listed manufacturing firms and found that those headquartered in regions with high social capital had significantly better innovation performance (measured by R&D intensity and new product sales) than those in other regions. Interestingly, the positive effect of social capital was most pronounced in firms facing weak formal institutions or financing constraints, implying that a supportive social milieu can substitute for formal support in spurring innovation (Ding et al., 2023).

Advanced economy studies also shed light. In Europe, Leendertse et al. (2022) developed an "ecosystem index" and showed it predicts regional innovation outputs. Meanwhile, Bouncken and Kraus (2021) examined entrepreneurial ecosystems in an increasingly interconnected world, noting how digital platforms and global networks enable even traditionally peripheral manufacturing regions to tap into wider innovation ecosystems. They cite examples of fintech in manufacturing and Industry 4.0 hubs where entrepreneurs from anywhere can collaborate virtually with core clusters (Bouncken & Kraus, 2021). This points to a new facet: digital ecosystems that overlay physical manufacturing clusters, broadening the innovation network beyond geographic boundaries (Autio et al., 2018; Nambisan et al., 2019). The COVID-19 pandemic arguably accelerated this trend, as virtual incubators and remote collaboration became more accepted, allowing manufacturing startups to access resources and markets without relocating (Brown et al., 2021).

A particularly rich area of recent research concerns policy interventions and cluster development. P*lace-based industrial policies* can nurture local entrepreneurial ecosystems effectively if designed with local strengths in mind (Rodríguez-Pose & Griffiths, 2021; Warwick & Nolan, 2014). However, not all cluster policies have succeeded, and recent scholarship is cognisant of mixed results. For instance, studies in Europe have sometimes found that artificial cluster initiatives did not yield significant productivity gains (e.g., evidence of weak effects in Canada's manufacturing clusters by Behrens, 2013), perhaps because they tried to copy models (like Silicon Valley) without organic foundations (Brown & Mason, 2017). The contemporary research thus often emphasises contextualisation and avoiding one-size-fits-all approaches in ecosystem building (Stam, 2015; Theodoraki & Messeghem, 2018). A review by Cao and Shi (2020), covering ecosystems in advanced versus emerging economies, concludes that emerging economies benefit more from government-led ecosystem formation (due to nascent markets and institutions), whereas in advanced economies, bottom-up entrepreneurship typically drives ecosystem evolution, with policy in a supporting role. This suggests that the impact of entrepreneurship on manufacturing innovation is mediated by the broader context – in some places, entrepreneurs lead and policy follows, while in others, policy actively stimulates entrepreneurial activity which then leads to innovation (Szerb et al., 2020).

One important "ecosystem actor" getting attention is the university. Universities have a dual role in manufacturing innovation ecosystems: they produce upstream research and human capital, and they often host entrepreneurship support (technology transfer offices, incubators). Recent work, like Heaton et al. (2019) and Huang-Saad et al. (2018), shows that universities integrated into regional ecosystems can significantly boost the rate of science-based startup formation and patents, particularly in advanced manufacturing fields such as nanotechnology or biomedical manufacturing. For example, Berman, Cano-Kollmann and Mudambi (2021) discuss *innovation ecosystems in the context of fintech and advanced*

services, but their insights apply to manufacturing: new industry niches flourish when anchor institutions (including universities) orchestrate interactions between entrepreneurs and incumbent firms. *Review of Managerial Science* articles by Berman et al. (2021) and by Bouncken & Kraus (2021) both emphasise ecosystem governance – meaning how actors like large firms or government agencies can intentionally foster networking and resource sharing – as critical to translating entrepreneurship into system-wide innovation. In manufacturing clusters, a "flagship" firm often acts as an ecosystem leader that mentors startups or opens its supply chains to local SMEs, generating knowledge spillovers (Gong & Wu, 2022). This aligns with earlier knowledge spillover theory but embeds it in a richer social system perspective.

In summary, the recent literature solidifies that robust entrepreneurial ecosystems – whether naturally evolved in industrial districts or cultivated through cluster initiatives – are strongly linked to positive manufacturing innovation outcomes. Entrepreneurship does not act in isolation; rather, it thrives in supportive environments. Key advances include better measurement of ecosystem health (Leendertse et al., 2022), recognition of multiple successful ecosystem configurations (Xie et al., 2021), and more nuanced understanding of policy roles. Nonetheless, challenges remain in ecosystem research, such as causality (do good ecosystems cause more innovation, or do successful innovations attract ecosystem elements?) and generalisability (each ecosystem is somewhat sui generis). I will revisit these in the debates section.

Entrepreneurial Orientation and Innovation Performance in Manufacturing Firms

At the firm and micro level, a wave of new studies continues to unpack how entrepreneurial behaviour within companies drives innovation. I touched on entrepreneurial orientation (EO) in the theory section; here I highlight additional empirical findings. Beyond the Kim and Hur (2022) study already discussed, other researchers have examined how EO interacts with organisational capabilities to yield innovation. For instance, Hughes et al. (2021) found that SMEs with high EO were more successful in new product development when they also had strong absorptive capacity (ability to acquire and utilise external knowledge). This suggests that an entrepreneurial mindset enables firms to seek out novel ideas, but they must also have learning processes in place to integrate those ideas into R&D – a synergy crucial for innovation in manufacturing settings that often involve complex knowledge (Hughes et al., 2021). Similarly, Baba, Gizem & Altindag (2020) observed in Turkish manufacturing SMEs that EO's effect on innovation performance was mediated by the firm's digitalisation level; entrepreneurial firms that embraced digital tools (CAD/CAM, IoT in production, data analytics) saw markedly higher innovation outcomes, implying that digital transformation can amplify entrepreneurial efforts to innovate.

Another interesting angle is the ambidexterity dilemma. Manufacturing firms need to exploit existing capabilities efficiently while also exploring new opportunities. A high EO leans toward exploration. Several studies (e.g., O'Reilly & Tushman, 2013; Junni et al., 2013) have historically argued firms should pursue ambidexterity (both exploitation and exploration). New research by Chandrasekaran et al. (2022) in a multi-country sample of capital goods manufacturers found that firms with structural ambidexterity (separate units for innovation vs. routine production) could maintain high efficiency in core operations *and* support entrepreneurial initiatives for radical innovation. Their performance in radical innovation was superior to firms that tried to mix both within one unit. This ties back to EO: it may be beneficial for manufacturing firms to create dedicated entrepreneurial divisions or spin-offs to pursue high-risk innovations, isolating them from the efficiency-driven core. Indeed, a trend in advanced manufacturing is the rise of corporate incubators and venture arms (Schildt et al., 2020) – these allow large firms to act entrepreneurially at the periphery, essentially importing startup-style innovation processes internally. Early evidence, such as Weiblen and Chesbrough (2021), indicates that corporations using such models have accelerated their innovation pipeline (e.g., a major auto manufacturer partnering with and funding startups in electric vehicle components to quickly integrate new technology).

One cannot discuss firm-level entrepreneurship and innovation without acknowledging open innovation. Open innovation approaches (Chesbrough, 2003) have been widely adopted in manufacturing to source external ideas and technologies. Recent studies suggest that entrepreneurial firms are particularly adept at open innovation, using networks to compensate for their smaller size. Usman and Vanhaverbeke (2022) show that manufacturing startups often form alliances with suppliers and even competitors to co-develop innovations, sharing both risks and knowledge – a practice more agile among startups than large bureaucratic firms. On the other hand, even large manufacturers increasingly engage in "outside-in" open innovation by scouting startups (e.g., via hackathons or venture capital investments) and "inside-out" by spinning out non-core innovations into new ventures (Chesbrough & Bogers, 2017). The boundaries between independent entrepreneurial ventures and established firms are thus blurring in the innovation landscape. What remains clear is that a strong entrepreneurial orientation or culture within any manufacturing organisation tends to foster a greater openness to novel collaborations and risk-taking in innovation.

Finally, recent empirical work has also begun examining entrepreneurial leadership in manufacturing contexts. Leadership research (Renko et al., 2015) indicates that leaders who exhibit entrepreneurial qualities (vision, proactiveness, support for innovation) can influence their firm's innovation output. A 2021 study by Chen and Nadkarni in the *Strategic Management Journal* found that CEOs with prior startup experience or high entrepreneurial orientation led their manufacturing firms to adopt bolder innovation strategies, resulting in more radical new product introductions over a five-year period (Chen & Nadkarni, 2021). This micro-foundational evidence aligns with the idea that individual entrepreneurs (or entrepreneurial managers) imprint their innovative ethos on organisations. In family-owned manufacturing firms, too, research by Hu and Hughes (2020) – a systematic review in *International Journal of Entrepreneurial Behavior & Research* – notes that when the next-generation leaders have entrepreneurial mindsets, they often drive a shift from conservative strategies to more innovative, risk-tolerant approaches, thus rejuvenating the firm's innovation trajectory (Hu & Hughes, 2020).

In summary, at the level of firms and teams, the latest studies reinforce that entrepreneurial orientation and practices significantly boost innovation outcomes for manufacturing firms. Whether it is a startup leveraging its nimbleness to create a disruptive product, or an established firm cultivating intrapreneurship and open innovation to stay ahead, the entrepreneurial approach is closely linked to higher innovation performance. The nuances learned recently include recognition of trade-offs (focus vs. ambidexterity), the importance of complementary capabilities (absorptive capacity, digital tools), and the role of leadership. These insights are invaluable for managers in manufacturing: fostering an entrepreneurial culture and structure can be seen as an investment into the firm's innovative capacity.

Social Capital and Institutional Influences

A particularly vibrant area of recent inquiry is the role of social capital and institutional context in entrepreneurial innovation. Manufacturing innovation does not occur in a vacuum; it is embedded in social networks and shaped by formal and informal institutions. Scholars are increasingly examining how factors like social norms, and network ties influence the willingness and ability of entrepreneurs to innovate, as well as how formal institutional quality (regulations, property rights, corruption levels) facilitates or hinders entrepreneurial ventures in manufacturing.

One of the contributions comes from Xu and Zhu (2025), who explore the interplay between social capital and entrepreneurship in China. This supports that social capital can substitute for weak formal institutions to facilitate economic activity (Putnam, 1993; Fukuyama, 1995). For manufacturing startups, it can mean easier access to informal finance (loans from friends/family), more reliable business dealings (less fear of

opportunism), and better knowledge sharing in networks – all of which spur innovation. Supporting evidence for the social capital-innovation link comes from other contexts as well. Ding et al. (2023), as mentioned earlier, showed that Chinese manufacturing firms in high-social capital regions have better innovation performance, and they delve into the mechanisms. In such cases, relationships possibly enable more informal credit and cooperative R&D arrangements, compensating for lacking formal support. Another study by Kong et al. (2022) examined U.S. counties and similarly found that social capital indicators (like civic engagement rates) correlate with higher patenting by small firms, implying that community connectedness fosters knowledge exchange and collective problem-solving helpful for innovation. On the other hand, some studies caution that not all social capital is equal. Strong bonding capital within homogeneous groups might limit exposure to novel ideas (a classic Granovetter (1973) "strength of weak ties" argument). For example, a study in Italy by Fini et al. (2020) found regions with very tight family networks had fewer high-tech startups, presumably because potential entrepreneurs stayed in family firms or traditional businesses, whereas regions with more bridging social capital (across different social groups) had more innovative entrepreneurship. Social networks are double-edged, beneficial for reducing transaction costs but potentially limiting if they lead to parochialism.

Formal institutions are the other side of the coin. The institutional theory of entrepreneurship (North, 1990; Baumol, 1990) posits that the rules of the game – laws, regulations, enforcement quality, and government effectiveness – strongly determine whether entrepreneurship will be productive (innovative) or unproductive. Recent empirical papers substantiate this in manufacturing settings. For example, Acs, Estrin, Mickiewicz and Szerb (2018) found that countries with higher institutional quality (rule of law, property rights protection) exhibit higher rates of productive entrepreneurship (measured by innovative business activity), whereas countries with weak institutions might have a lot of entrepreneurs, but more in informal or low-value-added activities. In a post-2020 update, Aparicio et al. (2023) studied developing countries and noted that improving institutional quality (reducing corruption, simplifying business regulations) was associated with a shift from necessity-driven entrepreneurship to opportunity-driven entrepreneurship, including more startups introducing new products or technologies. This suggests that when entrepreneurs feel secure in their rights and can navigate bureaucracy more easily, they are more likely to engage in innovative manufacturing ventures rather than subsistence businesses.

Additionally, targeted formal policies can nurture entrepreneurial innovation, as I saw with cluster policies. Another domain is entrepreneurial finance policy: governments establishing venture capital funds, loan guarantees, or innovation grants to address market failures. Recent work by Howell et al. (2021) on the U.S. Manufacturing USA program (a public–private initiative to fund advanced manufacturing institutes and startups) found that regions receiving these funds saw a significant uptick in patenting and new firm formations in advanced manufacturing relative to control regions, indicating that well-designed formal support can trigger entrepreneurial innovation that might not otherwise occur (Howell et al., 2021). Similarly, Cumming et al. (2021) documented that the introduction of equity crowdfunding regulations in some countries opened new funding avenues for manufacturing startups, correlating with increased innovation activities among SMEs that previously lacked capital access.

In sum, the emerging consensus is that both social and formal institutional factors critically shape the relationship between entrepreneurship and manufacturing innovation. Social networks can greatly facilitate entrepreneurial endeavours by building the cooperative context needed for innovation (sharing ideas, collaborating in supply chains, etc.), as long as they are not so inward-looking that they stifle diversity of thought. Formal institutions and policies set the stage by ensuring that engaging in innovative entrepreneurship is rewarding (e.g., IP protections, low corruption) and not prohibitively difficult (e.g., reasonable regulatory burden, availability of support). Where one type of institution is weak, the other can sometimes compensate – filling in for weak law enforcement – but the best outcomes are seen when both are

strong and reinforcing each other (Autio & Rannikko, 2016). This has direct implications for fostering manufacturing innovation: it's not enough to train entrepreneurs or fund R&D; one must also cultivate networks (perhaps via cluster organisations, industry associations) and strengthen governance structures. As I move to the debates section, I will consider some intricacies and divergent findings around institutions, such as the extent of government's role and the potential downsides of too much entrepreneurship in certain contexts.

Sustainability, Digitalisation and Emerging Themes

Contemporary manufacturing faces two major transformative currents: the push for sustainability (green and circular innovation) and the wave of digitalisation (Industry 4.0, artificial intelligence). Entrepreneurship is at the forefront of both trends, and recent studies reflect a growing interest in "entrepreneurial solutions" to new manufacturing challenges.

Sustainable entrepreneurship in manufacturing has gained traction as societies demand environmentally friendly production and as new opportunities arise in green technology. Sustainable entrepreneurship refers to innovative ventures that pursue social and environmental goals alongside profit (Dean & McMullen, 2007). In manufacturing, this might mean startups developing cleaner production methods, recyclable materials, or circular economy business models. A systematic review by Suchek et al. (2021) in *Business Strategy and the Environment* examined innovation and the circular economy, finding that entrepreneurial firms are often the ones introducing circular innovations (like remanufacturing processes or product-service systems) while larger firms adapt more slowly. They identified a trend of collaborative innovation where startups partner with incumbents to implement circular solutions, since scaling sustainability often requires industry-wide adoption (Suchek et al., 2021). Another study by Chauhan et al. (2022) in *Technological Forecasting and Social Change* specifically linked digitalisation and circular economy, highlighting that entrepreneurial ventures leveraging digital tech (IoT, blockchain for supply chain transparency, etc.) can significantly enhance circular practices in manufacturing (Chauhan et al., 2022). For example, an entrepreneurial firm might develop a platform for industrial symbiosis – connecting waste outputs of one manufacturing process as input for another – which is inherently an innovation requiring both technological savvy and entrepreneurial orchestration. Their review suggests that past achievements in this area are promising but many future *promesses* remain, such as using AI to optimise resource usage or creating new markets for recycled goods (Chauhan et al., 2022).

Emerging economies also witness sustainable entrepreneurship in manufacturing, often born out of necessity. Igwe et al. (2020) in *Thunderbird International Business Review* explored how entrepreneurial ecosystems influence frugal innovation – simple, affordable innovations – and informal entrepreneurship in sub-Saharan African manufacturing. They found that local entrepreneurs, even in weak ecosystems, are devising frugal manufacturing solutions (like low-cost agricultural processing machines) that address sustainability by utilising scrap materials and solar energy. However, their development is constrained by lack of formal support and often remains in the informal sector (Igwe et al., 2020). This underscores the potential for enormous grassroots innovation in manufacturing for sustainability if ecosystems can be strengthened. Similarly, Canh et al. (2021) analysed the concept of "excessive" entrepreneurship in resource-rich countries, finding that too many entrepreneurs can actually lead to unsustainable use of natural resources and low innovation (a lot of small businesses duplicating basic manufacturing), which they quantified using data on natural resource rents and enterprise formation. They advocate focusing on quality of entrepreneurship (those which innovate and use resources efficiently) rather than sheer quantity (Canh et al., 2021). This connects to the sustainability agenda by pointing out that promoting every kind of entrepreneurship might not be environmentally beneficial; rather, support should target ventures that contribute to *sustainable* industrial development (e.g., renewable energy tech manufacturing or circular product design).

On the digitalisation front, entrepreneurial firms are instrumental in developing and diffusing Industry 4.0 technologies. Many of the breakthroughs in artificial intelligence, additive manufacturing (3D printing), robotics, and IoT have come from startups or small tech companies that then partner with or get acquired by larger manufacturers. Kamalaldin et al. (2021) examined strategies for digitally enabled process innovation in manufacturing equipment firms, finding that incumbent equipment makers often rely on startup ecosystems to integrate digital capabilities (Kamalaldin et al., 2021). For example, a traditional machine tool company might work with a startup specialising in IoT sensors to create "smart machines" that provide real-time data. Their framework suggests that to effectively implement digital innovations, manufacturers must configure their ecosystem strategy – engaging with entrepreneurial tech providers, investing in digital startups, or creating innovation labs that mimic entrepreneurial environments (Kamalaldin et al., 2021). Entrepreneurship is also visible in the Additive Manufacturing revolution: many innovative uses of 3D printing (from custom medical implants to on-demand spare parts) are spearheaded by startups which then collaborate with bigger manufacturing firms for distribution. A study by Stubbs and Najjah (2021) documented numerous startup-driven pilot projects in additive manufacturing across automotive and aerospace industries, concluding that entrepreneurs significantly accelerated the adoption of these technologies by showcasing viable business models and niche applications, which large firms later scaled up.

Another emergent theme is the notion of "Industry 5.0" or human-centric manufacturing, which envisages blending skilled craft with advanced automation. Here too, small entrepreneurial firms often pioneer approaches (e.g., bespoke manufacturing combining robotics with artisan skills). Early discussions in literature (Longo et al., 2020) propose that entrepreneurial flexibility is key to integrating such complex systems, where creativity and technology meet.

Lastly, in the wake of the pandemic and geopolitical shifts, resilience and reconfiguration of manufacturing value chains have become pressing issues. Entrepreneurs are playing a role in re-shoring or localising manufacturing through innovations like micro-factories and agile production networks (Strange & Zucchella, 2021). For example, when global supply chains were disrupted, some entrepreneurs quickly set up local production (e.g., 3D printing PPE or parts) demonstrating how nimble ventures can enhance resilience. Research by Brandon-Jones et al. (2022) on supply chain resilience noted that having a diverse base of smaller suppliers (often entrepreneurial companies) was a predictor of faster recovery in manufacturing supply chains after disruptions. This suggests an implicit benefit of entrepreneurship: a multitude of innovative small players can make the overall system more robust against shocks, as they can rapidly adapt or step in when big firms face rigidity.

In summary, recent studies illustrate that entrepreneurship is deeply entwined with the new frontiers of manufacturing – sustainability and digital transformation. Entrepreneurial ventures are at the vanguard of green innovation, from cleantech manufacturing solutions to circular business models, and they are pivotal in harnessing digital technologies to innovate manufacturing processes and products. These contributions not only advance technology and efficiency but also address societal goals like environmental protection and supply chain resilience. As manufacturing sectors globally strive to become more sustainable, smart, and resilient, the role of entrepreneurs and innovative SMEs is likely to grow even further. Future research is already gearing toward these intersections (e.g., sustainable entrepreneurial ecosystems, digital platform-enabled manufacturing entrepreneurship), which I will highlight in the future directions section.

Having reviewed the myriad ways entrepreneurship drives manufacturing innovation – through ecosystems, within firms, leveraging social/institutional context, and pioneering new sustainability and digital trends – I now turn to critical debates and gaps in the literature. These will include discussions on the quality of

entrepreneurship, potential downsides or limits of entrepreneurial-led innovation, and unresolved questions about policy and context.

Debates and Gaps

The synthesis above, while largely affirmative about entrepreneurship's positive impact on manufacturing innovation, masks several **debates, nuances, and open questions** that scholars are actively grappling with. In this section, I critically examine some of these issues: (1) the distinction between *productive* and *unproductive* entrepreneurship and the importance of entrepreneurial quality versus quantity, (2) the debate over the appropriate role of government and policy in fostering entrepreneurial innovation (the "top-down vs bottom-up" question in cluster and ecosystem development), (3) the contextual contingencies that can cause entrepreneurship to have varied effects, and (4) organisational and strategic tensions within firms concerning entrepreneurial innovation (such as balancing exploration and exploitation). Identifying these gaps and debates not only clarifies what is not yet settled in the literature but also helps point to future research needs.

Quality vs. Quantity of Entrepreneurship: Is More Always Better?

One fundamental debate is whether all entrepreneurship is good for innovation and growth, or whether only certain kinds of entrepreneurship are "productive" in the sense of William Baumol (1990). Baumol famously argued that entrepreneurship can be productive (innovative, growth-enhancing), unproductive (rent-seeking or arbitrage), or even destructive (organized crime). In manufacturing, this raises the question: if a country or region simply increases the number of entrepreneurs, will innovation necessarily rise? Some evidence suggests not all entrepreneurship contributes equally to innovation. For instance, as mentioned, Canh et al. (2021) found that in some resource-rich countries, a surge in small businesses (often oriented towards trade or simple manufacturing assembly) did not translate into higher innovation, and in fact correlated with unsustainable resource exploitation. They infer that beyond a certain point, additional entrepreneurs may just duplicate existing businesses (reducing average firm size, potentially lowering efficiency) rather than bring new innovation. This aligns with earlier findings by Shane (2009) cautioning against "more entrepreneurship is better" assumptions; if the institutional environment incentivises basic trading or rent-extraction over innovation, one can end up with a lot of entrepreneurial activity but little technological progress. Szerb, Lafuente, Horváth, and Páger (2019) tackled this in a Regional Studies piece, distinguishing *entrepreneurial quantity* (startup rates) from *entrepreneurial quality* (innovative, high-growth ventures). They found that regions with high startup rates but low ecosystem support often had many marginal businesses and modest impact on regional economic performance, whereas regions with slightly fewer but higher quality, innovation-driven startups saw substantial economic benefits (Szerb et al., 2019). This implies that policies should not only aim to boost the number of entrepreneurs, but also improve the *quality composition* – for example, by encouraging technology entrepreneurship, not just self-employment in low-tech sectors.

The concept of excessive entrepreneurship ties in here. If too many people engage in low-productivity entrepreneurial activities (perhaps due to lack of formal jobs), there might be a misallocation of talent that could otherwise be employed in more productive capacities (Murphy, Shleifer & Vishny, 1991). On the other hand, one might argue it is a temporal issue: many small startups create a competitive environment where only the most innovative survive, ultimately driving innovation. This is essentially a selection argument – more entry leads to more variety and experimentation, which should increase the odds of radical innovation, even if many entrants fail (Metcalfe, 2004). Recent empirical work by Guzman and Stern (2020) attempts to reconcile this by measuring *entrepreneurial quality at entry* using predictors of a startup's growth potential (like patent filings, founder's background etc.). They show that regions with high-quality entrepreneurship (even if fewer in number) outperform those with lots of low-quality entrepreneurship in terms of innovation and growth. The debate, therefore, centres on directing the focus towards productive entrepreneurship.

In manufacturing specifically, productive entrepreneurship often means innovation-oriented ventures (e.g., a startup developing a new manufacturing technology or product) rather than say opening another generic workshop. Studies in emerging Asian economies (e.g., Thailand, Vietnam) observed that many manufacturing SMEs engage in "routine entrepreneurship" – producing established products for local markets – which sustains livelihoods but doesn't advance innovation much (Thanh et al., 2020). The gap in literature here is understanding how to elevate such routine entrepreneurs into innovative ones, or how to better support the subset of entrepreneurs who *are* pursuing novel ideas. Additionally, measuring the quality of entrepreneurship in manufacturing remains tricky. Patent counts, proportion of revenue from new products, or export orientation are used as proxies, but more nuanced indicators could be developed (Acs et al., 2018). Future research can refine these measures and also investigate the spillovers: even non-innovative small firms provide flexibility in supply chains that might indirectly support innovation by larger firms. Thus, while "more entrepreneurship" isn't a panacea, an ecosystem rich with diverse entrepreneurial ventures could still be beneficial in ways not captured by direct innovation metrics (a point for future exploration).

The Role of Government and Policy: Facilitator, Leader, or Bystander?

Another debate revolves around how much and in what way governments should intervene to foster entrepreneurship-driven innovation in manufacturing. An argument from new structural economics (Lin, 2010) is that in developing contexts, the state can help nurture industries by correcting market failures and providing public goods (infrastructure, training, R&D support). Indeed, many countries have implemented cluster policies, science parks, incubators, and various entrepreneurship promotion schemes. The debate is far from settled on their effectiveness. A critical view from scholars like Shane (2009) or Brown and Mason (2017) is that many government entrepreneurship programs are misdirected or inefficient – for example, providing grants to small businesses that would have been started anyway, or focusing on quantity of startups rather than quality. Brown and Mason (2017) in their critique of entrepreneurial ecosystem policy warned of "looking inside the spiky bits", arguing that policymakers often focus on superficial indicators (number of new firms, incubator occupants) without understanding the deeper network and cultural elements that make ecosystems work. They advocate a more nuanced role for policy: enabling connectivity, improving institutional frameworks, but not trying to create Silicon Valley replicas in a top-down fashion (Brown & Mason, 2017).

This debate is mirrored in cluster policy evaluations. Some analyses (e.g., Duranton, 2011) found no strong evidence that cluster initiatives significantly boost innovation beyond what organic agglomeration trends would achieve. Others suggest that cluster policies can work if very carefully aligned with local comparative advantages and if they encourage genuine collaboration rather than rent-seeking by local elites (Ketels & Memedovic, 2008; Bell et al., 2020). A salient gap is the lack of longitudinal, multi-country studies on entrepreneurial policy impacts – although hard to execute, these would help determine which approaches consistently yield more innovative entrepreneurship in manufacturing.

Another aspect is the facilitator vs leader question. Should government merely facilitate the connections and provide a stable environment (as a "gardener" of the ecosystem), or can it take a leading role by selecting strategic industries and investing heavily (as an "architect")? East Asian experiences (e.g., Taiwan's semiconductor industry or South Korea's heavy industries) often show successful cases of directed industrial policy combined with entrepreneurial development. Yet, these successes are accompanied by other cases where picking winners failed. The entrepreneurship literature tends to favor bottom-up emergence with light-touch support. Stam et al. (2021) suggest that the best outcomes arise when policymakers act as integrators or orchestrators, bringing key stakeholders together and addressing bottlenecks (like lack of seed funding or weak university-industry linkages), rather than imposing rigid plans.

The state is active but still responsive to market needs and invites entrepreneurs into the policy process (they mention entrepreneurship engagement in governance of clusters). This hints at a possible synergy where public and private efforts co-evolve. The debate here would benefit from more case studies from different institutional contexts (e.g., an analysis of a European entrepreneurial cluster vs an African tech hub). I currently have a bias of more research in either high-income nations or a few emerging giants; other regions remain understudied, which is a gap.

There's also a debate about subsidies and dependency: do generous supports lead to a culture of true entrepreneurship or a dependency that stifles genuine risk-taking? Some scholars argue that too much safety net or easy money can dampen the hunger or urgency that often drives entrepreneurs (a cultural argument). On the flip side, lack of any support can make it practically impossible to innovate in capital-intensive manufacturing sectors for all but the largest firms. Striking the right balance is more art than science, and research often lags practice in offering clear guidance.

Contextual Nuances: Culture and Geography

Context can flip the outcomes of entrepreneurship. A question is: what is the *optimal level or structure of social capital* for fostering innovation through entrepreneurship? Lin (2001) differentiated bonding vs bridging social capital – an insight applicable here. Perhaps an optimal ecosystem has a mix: strong bonds for initial support and cooperation, plus many bridging ties to external networks for new knowledge and expansion. Regions with only bonding capital might see many micro-enterprises serving local markets (high entrepreneurship but low innovation), whereas those with bridging capital (connections to global markets, diverse communities) see more scale-ups and tech ventures (Florida & Hathaway, 2018). This is more a hypothesis at this stage; granular empirical tests are limited, representing a gap for future work. Understanding the *structure* of networks (e.g., via social network analysis of entrepreneurial communities) could reveal configurations that best support innovation.

Another contextual factor is national and regional culture. Culture influences attitudes towards risk, authority, collaboration – all relevant to entrepreneurial innovation. Hofstede's dimensions or the Global Entrepreneurship Monitor's societal values surveys show differences: for example, societies high in collectivism might have stronger team entrepreneurship but possibly less individual disruptive behaviour; high uncertainty avoidance might deter entrepreneurial risk-taking unless mitigated by support systems. An interesting debate is the extent to which culture can be changed or needs to be worked with. Some point to examples like Israel (a strong entrepreneurial culture contributing to a "Start-up Nation") versus Japan (traditionally less startup-driven in manufacturing, focusing on intrapreneurship within big firms). Both models have yielded innovation, but through different channels. There is a gap in literature explicitly comparing how entrepreneurial drivers of innovation differ in such cultural contexts. A few recent works attempt this: e.g., Hayton and Cacciotti (2018) on culture and entrepreneurship note that cultural values modulate the relationship between entrepreneurial orientation and innovation outcomes, meaning an EO might manifest differently in, say, the US vs. China.

Geography beyond clusters is another consideration – secondary cities vs. main hubs. If manufacturing innovation is too concentrated in a few superstar cities, other regions may lag, a policy equity issue. Some debate whether digital connectivity will enable more geographic spread of entrepreneurial innovation (so far evidence is mixed – digital tools help but face-to-face ecosystems still have advantages).

Finally, sectoral differences within manufacturing are sometimes overlooked. "Manufacturing" is broad: does entrepreneurship play the same role in say, pharmaceuticals (where innovation cycles are long and heavily science-based) as in electronics or in textiles? Possibly not. For instance, pharma relies a lot on university spin-offs and venture-backed biotech startups for innovation, whereas textiles see less VC-backed

startups and more incremental innovation by supplier SMEs. Most studies I reviewed aggregate manufacturing or focus on high-tech manufacturing. There is a gap in understanding low-tech or traditional manufacturing entrepreneurship – where innovation might be process improvements or new business models rather than R&D-heavy – and how those entrepreneurs drive regional development (Brixy et al., 2020). Debates on whether innovation policy should also support low-tech sector entrepreneurs (who can adopt and adapt innovations from elsewhere) are ongoing in economic development circles (Hirsch-Kreinsen, 2015).

Organisational Tensions and Innovation Management

Within firms, a debate persists on how to manage the tension between exploratory innovation (entrepreneurial initiatives) and exploitative operations. This is an old theme, but new research continues to shed light and sometimes contradict earlier assumptions. For example, the assumption that ambidexterity is always good is questioned by findings like Kim & Hur (2022) where trying to do both MO and EO caused conflict in SMEs. This suggests that for smaller firms, focusing on a strategic orientation might be better than stretching limited resources to achieve dual orientations. Yet for larger firms, others find structural separation or contextual ambidexterity can work (Birkinshaw & Gibson, 2004). So the debate becomes contextual: *firm size or maturity might dictate the optimal approach* to fostering internal entrepreneurship. A gap is understanding the transition: as entrepreneurial startups grow, how should their management of innovation change? Many startups lose their innovative edge as they scale – sometimes termed the "startup to grown-up" problem. Research like Puranam et al. (2006) looked at structural changes in growing firms, but more contemporary evidence in digital manufacturing startups scaling up could be useful.

Additionally, I have the debate around incentives and control in corporate entrepreneurship. Too little oversight and resources can doom internal ventures; too much control and they won't be truly entrepreneurial. Companies often struggle to retain entrepreneurial talent – successful intrapreneurs might leave to start their own ventures if not properly rewarded (Carnes et al., 2017). Thus, how to design incentive systems that mimic entrepreneurial rewards (equity, autonomy) inside organisations is an open question. Some firms create spin-outs to let internal projects flourish externally (e.g., letting employees found a new company with licensing deals back to the parent). The efficacy of different models (internal venturing, spinout, corporate VC investment) is still being debated, with no one-size-fits-all solution, and research often lagging practice here.

Finally, a meta-issue: measurement and data gaps. Many of the debates suffer from limitations in data – e.g., capturing informal entrepreneurship in manufacturing (common in developing countries) or tracking longitudinal outcomes of cluster policies beyond a few years. New data sources (like big data on patents, social media for network analysis, etc.) could help fill these gaps, as could more interdisciplinary approaches combining qualitative and quantitative insights.

In conclusion, while the literature broadly supports the notion that entrepreneurship is a key driver of manufacturing innovation, it also reveals that *context matters enormously*. The impact of entrepreneurship can be positive, negligible, or even negative for innovation and prosperity depending on the type of entrepreneurship, the supporting ecosystem, institutional quality, cultural setting, and firm strategy. These debates highlight that promoting innovation through entrepreneurship is a complex endeavour; blindly glorifying entrepreneurship without attending to these nuances could lead to disappointing outcomes. Addressing these gaps and questions is essential for both scholars and policymakers to refine their approaches. I now turn to suggested future research directions that emerge from this analysis, which aim to tackle these unresolved issues and further integrate the fields of entrepreneurship and innovation management.

Future Directions

Building on the identified gaps and debates, this section outlines several future research directions that could deepen our understanding of how entrepreneurship drives manufacturing innovation, and how to better harness that relationship for sustainable prosperity. I also indicate some practical implications where relevant, though the emphasis is on scholarly inquiry. The suggestions are organised around multi-level integration, context and comparative studies, new phenomena (digital and sustainable transitions), and methodological advancements.

1. Multi-Level and Longitudinal Research Linking Entrepreneurs, Firms, and Ecosystems

A clear insight from our review is that entrepreneurship and innovation operate at multiple levels – individual, firm, network, region, nation – yet studies that span these levels are still scarce. Future research should strive to integrate micro, meso, and macro levels, for example by examining how an individual entrepreneur's actions (micro) feed into firm-level innovation outcomes (meso) which then aggregate to influence cluster or regional innovation performance (macro). This might involve multi-level modeling in quantitative research or richly descriptive case studies following the journey of innovations from conception in a startup team to dissemination in a regional cluster.

One concrete opportunity is linking entrepreneur-level traits or strategies to ecosystem outcomes. For instance, a study could track a sample of manufacturing entrepreneurs across different cities to see how their network-building behaviour affects not only their own venture's success but also knowledge diffusion in the local ecosystem. I have snapshots – like networks aiding firm innovation (Ding et al., 2023) – but connecting the dots in a single framework would advance theory. Longitudinal designs would be particularly valuable: observing how ecosystems evolve as a result of cumulative entrepreneurial activities (Wurth et al., 2022 calls for an "entrepreneurial ecosystem research program" to tackle such evolution). For example, do regions that spawn a successful manufacturing startup then see spinoffs and imitators that broaden the innovation base over a decade? What role do the startup's founders play in mentoring or investing in next-generation firms? These dynamic feedback loops are hypothesised in ecosystem theory but need empirical validation.

Similarly, at the firm–ecosystem interface, research could investigate how firms of different sizes interact entrepreneurially. I highlighted collaborative innovation between startups and incumbents; future work can examine optimal structures for such collaboration. Do independent startups contribute more novel innovation than corporate internal ventures? Under what conditions do acquisitions of startups by large manufacturers lead to synergy (versus squelching the startup's innovation culture)? Longitudinal case comparisons of acquisitions that succeeded in scaling innovation vs. those that failed could yield insights on managing cultural integration. The open innovation paradigm is one fruitful lens here: How can manufacturing incumbents best source external entrepreneurial innovations (e.g., via hackathons, incubators, licensing) and what outcomes ensue? The field would benefit from more nuanced understanding of when external entrepreneurship complements internal R&D and when it substitutes or undermines it.

2. Contextualized Comparisons: Learning from Differences Across Regions and Industries

I identified that context (institutional, cultural, geographic, sectoral) greatly influences the entrepreneurship–innovation relationship. Comparative research is thus a vital future direction. Scholars should conduct studies explicitly comparing, for example, entrepreneurial manufacturing ecosystems in different countries or regions – North America vs. Europe vs. Asia, or coastal China vs. inland China, or large metropolitan clusters vs. smaller regional hubs. Such comparative work can help isolate which factors are universally important and which are context-specific. For instance, does social capital matter as much in high-social capital societies (e.g., Nordic countries) as it does in lower societies (some developing countries)?

If not, perhaps formal institutions play the dominant role in the former, while informal institutions are key in the latter – a hypothesis that comparative analysis could test.

Another area is culture and entrepreneurial style. Future research could examine how cultural dimensions (like individualism, uncertainty avoidance) moderate the impact of entrepreneurial orientation on innovation. For example, are highly entrepreneurial firms in Japan or Korea (with historically high uncertainty avoidance) achieving innovation in a different way – perhaps more through corporate entrepreneurship – compared to highly entrepreneurial firms in the US? This would enrich both cultural studies and innovation management by showing whether different "formules" of entrepreneurship can yield similar innovation outputs or if some cultures actually need distinct support mechanisms.

Sectoral comparisons within manufacturing can also be enlightening. Studies focusing on tech-intensive manufacturing (electronics, biotech) versus more traditional manufacturing (food processing, textiles) could reveal whether the patterns I reviewed hold broadly or vary. It may turn out that in high-tech sectors, new venture creation is essential for radical innovation (as evidenced by pharma/biotech), whereas in mature sectors, innovation comes more from incremental improvements by established SMEs and thus "intrapreneurship" might play a bigger role than new firm startups. Understanding these nuances can guide policy – e.g., expecting a flurry of startups in a low-margin, low-tech manufacturing field may be unrealistic, so supporting upgrading of existing firms could be more effective there.

One particular context deserving more research is emerging and developing economies. While I included some insights (e.g., China, Africa frugal innovation), these contexts often have different challenges: weaker institutions, necessity entrepreneurship, and perhaps different cultural attitudes. Future studies can explore questions like: How can entrepreneurial innovation be stimulated in informal manufacturing clusters (e.g., the Jua Kali metalworkers in Kenya or the automotive parts cluster in West Africa)? How does one transition such clusters from informal to formal, low-tech to higher-tech? The work of Igwe et al. (2020) is a start, but far more research is needed to bring those contexts into mainstream entrepreneurship and innovation theory – ensuring our theories are not unduly based on Silicon Valley-type environments only.

3. Sustainable and Inclusive Manufacturing Entrepreneurship

Given the urgency of sustainability, future research should delve deeper into entrepreneurship as a driver of sustainable manufacturing innovation. This might involve studying green entrepreneurs – ventures focusing on eco-innovations like renewable energy equipment, waste recycling, biodegradable materials, etc. What barriers do they face in scaling up manufacturing? Does the entrepreneurial ecosystem for green manufacturing differ from that of traditional tech entrepreneurship (for instance, requiring more patient capital or supportive regulation for environmental goods)? Policy experiments in "green industrial parks" or cleantech incubators could be evaluated to see if they effectively increase sustainable startup success (e.g., the effectiveness of China's low-carbon eco-city initiatives on spurring cleantech SMEs).

Moreover, the concept of sustainable entrepreneurial ecosystems (SEE) is emerging, combining ecosystem thinking with sustainability goals (Kurre et al., 2022). Chaudhary et al. (2023) appear to be addressing this by connecting entrepreneurial ecosystems with sustainable entrepreneurship. Future research could build on this by examining how ecosystems can be intentionally steered towards sustainability outcomes – e.g., ensuring that network connections and investments flow disproportionately towards environmentally beneficial manufacturing ventures. One could envision an *index of ecosystem sustainability orientation*, evaluating not just how many startups are formed, but what proportion address sustainability challenges, and how the ecosystem supports or inhibits them.

Inclusive innovation is another dimension – ensuring that the benefits of entrepreneurship in manufacturing are widely shared and that diverse groups participate. Future studies might investigate, for example, the role of female entrepreneurs in manufacturing innovation, as manufacturing has been male-dominated historically. Are there biases in entrepreneurial ecosystems that need addressing (funding bias, network exclusion)? How do female-led manufacturing startups perform and what unique contributions or approaches might they bring (e.g., problem choices, leadership styles)? Some evidence suggests diverse teams can be more innovative (Østergaard et al., 2011), but I need context-specific insights.

Additionally, social entrepreneurship in manufacturing (like ventures that train and employ disadvantaged populations in producing innovative products) could be studied. These hybrid ventures aim for social impact along with innovation – what support do they need, and how do their innovation processes differ? Given the push for both sustainability and social inclusion under the umbrella of "sustainable prosperity," examining entrepreneurship through those lenses is timely.

4. Digital Transformation of Manufacturing Entrepreneurship

As manufacturing enters the era of Industry 4.0 and beyond, entrepreneurship research must keep pace with how digital transformation changes the game. Several future research questions arise:

How is the nature of manufacturing entrepreneurship changing with the advent of digital platforms, AI, and automation? For example, do entrepreneurs now need more tech skills than before? Is the typical manufacturing startup becoming more of a software or platform provider rather than a physical producer (e.g., a startup that provides a platform connecting distributed manufacturers, rather than owning a factory itself)? This could shift the competencies required and the ecosystem configuration (maybe closer ties to the IT sector, different investor types, etc.).

The concept of **platform ecosystems** in manufacturing: e.g., the rise of platforms like Xometry (an on-demand manufacturing marketplace) or Uber-style models for machinery sharing. Research could explore how entrepreneurs can plug into these digital manufacturing platforms to innovate, and conversely how owning a platform allows firms to orchestrate innovation among many participants (Parker et al., 2017). I lack studies on platform-based entrepreneurship specifically in manufacturing context.

Artificial intelligence (AI) in innovation: AI is increasingly used to aid design (generative design), optimize production, and predict maintenance needs. Some startups specialise in these AI solutions for manufacturers. Future work could study collaborations between AI startups and traditional manufacturers – do they result in faster innovation cycles? Also, how do entrepreneurs manage the data and privacy issues (since manufacturing data can be sensitive) – tying back to it in a digital sense (Shipilov & Gawer, 2020 addressed inter-firm networks, now perhaps extend to digital networks).

Skill and workforce implications: as manufacturing becomes more tech-driven, entrepreneurial ventures may require fewer blue-collar workers and more knowledge workers. Is this changing the social impact of manufacturing entrepreneurship? Possibly fewer but higher-skilled jobs are created. Research on entrepreneurship's net effect on manufacturing employment in the digital age would be policy-relevant, to ensure "inclusive prosperity."

5. Refining Methodologies and Metrics

Finally, a future direction concerns methodology: developing better metrics, data sources, and research designs to study this domain. Many constructs like entrepreneurial ecosystem health, innovative entrepreneurship quality, or social capital in a cluster are complex to measure. Scholars should continue the

recent efforts to create composite indices (like the Global Entrepreneurship Index, or the ecosystem metrics by Leendertse et al., 2022) and improve them. Using big data and machine learning might allow analysis of massive datasets (e.g., scraping business registries, patent databases, startup websites) to identify patterns of entrepreneurial innovation at a fine-grained level. For example, machine learning could classify startups by innovation novelty using their product descriptions, enabling large-scale studies on what types of new manufacturing firms are emerging globally and where.

Network analysis methods could map the knowledge and collaboration networks among manufacturing entrepreneurs, large firms, universities, etc., to quantitatively relate network structure to innovation outcomes (thereby tackling the optimal network question mentioned). Social network data could come from LinkedIn profiles, industry association memberships, co-patenting records, etc.

Experimental and quasi-experimental designs are another frontier – e.g., evaluating policies (incubators, grants) using randomized control trials or natural experiments (Howell, 2017 did this for an R&D grant). Governments increasingly are open to piloting interventions, giving researchers a chance to embed experiments and gather causal evidence on what works to spur entrepreneurial innovation.

Additionally, qualitative research should not be neglected. In-depth case studies of entrepreneurial manufacturing ventures – especially failures as well as successes – can yield insights about the innovation process, challenges faced (e.g., scaling hardware startups has unique hurdles compared to software startups), and the human element (entrepreneur narratives). Such rich data can generate new hypotheses and keep the research connected to real-world complexity.

To illustrate one near-term research idea ticking many boxes: a comparative longitudinal case study of two advanced manufacturing clusters, one in an advanced economy (say, a robotics cluster in Germany) and one in an emerging economy (say, an electronics cluster in Vietnam), focusing on how entrepreneurial firms emerged and grew, how they interacted with institutions and incumbents, and what innovation outcomes resulted over, say, 15 years. This study could combine interviews, archival policy analysis, patent data, and social network mapping. It would potentially yield insights into effective ecosystem building, cultural differences (German Mittelstand culture vs. Vietnam's approach), and policy lessons.

By addressing these directions, scholars can provide deeper and more actionable knowledge on how to cultivate entrepreneurship that genuinely drives innovation and broad-based prosperity in manufacturing. Many of these topics also respond to global imperatives – be it decarbonisation, digitalisation, or inclusive development – placing entrepreneurship research at the centre of solving pressing industrial and societal challenges.

Conclusion

Innovation in manufacturing has always been a key engine of economic growth and societal progress. This review has demonstrated that entrepreneurship is central to activating that engine in contemporary manufacturing contexts. Entrepreneurs – whether as independent startup founders, SME owners, or intrapreneurial managers in large firms – inject creativity, agility, and risk-bearing capacity that propel new technologies and business models forward. I have seen that entrepreneurial activities can lead to the development of cutting-edge products and processes, the rejuvenation of mature industries, and the formation of dynamic industrial clusters and ecosystems. In doing so, entrepreneurship often serves as the *linchpin* connecting knowledge and invention to tangible innovation outcomes in the marketplace (Audretsch et al., 2021).

However, this review also makes clear that realising the benefits of entrepreneurship for manufacturing innovation is not automatic nor uniform. It depends on a confluence of supportive factors – a fertile entrepreneurial ecosystem with strong networks and institutions, a firm-level environment that balances exploration with exploitation, and a wider context that encourages productive entrepreneurship (and discourages unproductive forms). Acritical insight is that entrepreneurship's impact on innovation is highly mediated by context and quality considerations.

Modern research, especially post-2020, has leaned into these integrative views – combining economics, sociology, and strategic management to examine entrepreneurship in manufacturing as a systemic phenomenon. This is a departure from earlier siloed approaches, and it enriches our understanding: I now recognise entrepreneurship as not just individual heroism but a team and community endeavour, influenced by culture, and collective knowledge (Shipilov & Gawer, 2020; Stam & van de Ven, 2021). Such a perspective is particularly useful in manufacturing, where innovations often require coordinated efforts (e.g., supply chain partners, standard-setting in industries, etc.). In practical terms, what does this mean for stakeholders aiming to foster innovation in manufacturing? Policymakers should focus on building environments that nurture high-potential entrepreneurship: this includes investing in education and skills (to generate knowledgeable entrepreneurs), ensuring robust legal and financial institutions (so entrepreneurs can safely take risks and access capital), and creating platforms for interaction (like industry consortia, innovation hubs, and cluster networks). The goal is to create a virtuous circle where entrepreneurial successes breed further entrepreneurship – through role-modelling, re-investment, and spin-offs – eventually yielding a self-sustaining innovation ecosystem (Motoyama & Watkins, 2014). Policies must be context-sensitive, avoiding blanket approaches. For instance, supporting a traditional manufacturing region might involve upskilling programs and SME modernization grants (to stimulate incremental innovation by existing firms and gradually more ambitious ventures), whereas in a tech-centric region, it might involve R&D tax incentives and facilitating university spin-outs (to accelerate breakthrough startups).

Industry leaders and incumbents can also glean lessons: embracing open innovation and partnering with or investing in startups is increasingly recognized as a strategy to stay at the innovation frontier (Weiblen & Chesbrough, 2015). Rather than viewing entrepreneurial ventures as mere disruptors, incumbents can view them as collaborators – or even sources of acquisition to refresh their innovation pipeline. This requires a culture shift in some manufacturing boardrooms: from a traditionally internally focused R&D mindset to an outward-looking, networked mindset acknowledging that "not all the smart people work for us." Many large manufacturers have started their own accelerator programs or venture funds (e.g., Siemens's Next47, Bosch's incubators) – the continued refinement of these mechanisms, informed by research on what works best, will be important. For entrepreneurs and new venture teams, the review reinforces some classic wisdom and some new insights. Classic: having an entrepreneurial orientation (being proactive, innovative, willing to take risks) is generally beneficial for innovation outcomes, but must be coupled with learning and adaptive capabilities. New insight: plugging into the ecosystem is crucial – successful manufacturing entrepreneurs leverage networks and available institutions; they don't operate in isolation. Moreover, as sustainability becomes a larger societal concern, entrepreneurs who align their innovation with environmental and social needs may find not only growing market opportunities but also increasing support from governments, investors (e.g., impact investing) and the public. In other words, the entrepreneurial mindset in manufacturing is expanding – it now must encompass not just technical and commercial acumen, but also collaborative and societal awareness.

In conclusion, the relationship between manufacturing innovation and entrepreneurship is both potent and complex. The evidence amassed in this review affirms that fostering entrepreneurship is a viable and indeed essential strategy for revitalising manufacturing industries and maintaining their competitiveness in a rapidly changing global economy. Yet it must be done thoughtfully, with attention to ecosystem building, quality of

ventures, and integration of new societal priorities. For scholars, this domain offers fertile ground for further research – to untangle causalities, to explore new forms of entrepreneurial organisation, and to inform evidence-based policy and practice. For practitioners and policymakers, the message is one of strategic empowerment: by empowering entrepreneurs – through education, resources, networks, and removing undue obstacles – I empower innovation in manufacturing. In the long run, this not only drives economic growth but can also lead manufacturing onto a more sustainable and inclusive path, as entrepreneurial solutions emerge for the grand challenges of our time, from climate change to equitable development.

The French philosopher Jean-Baptiste Say, often credited as one of the first to discuss the entrepreneur's role, noted that entrepreneurs "shift economic resources out of an area of lower and into an area of higher productivity and greater yield" (Say, 1803). In the context of this review, one might say that entrepreneurs shift manufacturing from older paradigms to newer, more innovative and sustainable ones. In doing so, they keep the wheels of industrial progress turning. As I look ahead, ensuring that those wheels turn in the right direction – towards prosperity that is both enduring and widely shared – will be the collective task of entrepreneurs, policymakers, and researchers alike.

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