

The Collaboration Paradox: Understanding the Barriers to Innovation Collaboration in Foundries and Metal-Forming Firms

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ABSTRACT

Empirical evidence demonstrates that there is an increasing need for firms to adopt collaborative innovation strategies. We explore three specific informational market failures, which may act as limiting factors to the extent of collaborative innovation among smaller firms. Drawing on data from semi-structured interviews, we explore how decision-makers in two traditional UK manufacturing sectors dominated by small and medium enterprises (SMEs) – metal-forming and metal-casting - acquire and evaluate knowledge about the trustworthiness, capabilities and strategic orientation of potential innovation partners. Our findings indicate that improving information availability about potential collaborators could significantly increase engagement in collaborative innovation and help overcome the collaboration paradox. Supply-chain partners and trade bodies emerge as ‘honest brokers’ who could address market failures generating public goods to overcome informational barriers to collaboration.

Keywords: Innovation Collaboration, SME productivity, Metal-Forming, Metal Casting

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1. INTRODUCTION

Innovation strategies based on collaboration can have significant advantages in terms of improved product quality, reduced time-to-market and risk-sharing (Kim et al. 2012; Love and Roper, 2015; Nambisan and Sawhney, 2011; Porter and Ketels, 2003; Schumpeter, 1934; Zawislak, 2012). Review articles indicate that firms that engage in collaborative innovation are often larger and have strong internal capabilities, which enable them to effectively appropriate the benefits of collaboration (Van de Vrande et al. 2009; Xiaobao et al. 2014). In such situations, collaboration may provide access to new knowledge which complements firms' existing knowledge base. For smaller firms where their internal knowledge base is weaker such complementarities may be harder for firms to capture. However, the benefits of innovation collaboration may be more significant for small firms due to the greater added value of external knowledge (Vahter et al. 2015). This defines the collaboration paradox: small firms have more to gain from collaboration for innovation but may find collaboration more difficult to implement.

The research literature now includes numerous studies which explore the benefits and barriers to innovation collaboration (Bigliardi and Galati, 2016; Chesbrough and Crowther, 2006; Lichenthaler and Ernst, 2009; Van de Vrande et al. 2009). Until recently, however, most studies have focussed on either larger firms or those in high technology sectors (Brunswick and Vanhaverbeke, 2014; Wynarczyk and Piperopoulos, 2013). Studies of innovation collaboration in small firms – particularly in traditional sectors – are more unusual despite their continuing importance in both developing and developed economies (Ayyagari et al. 2011; Cowling et al. 2015; Giaoutzim et al. 2016). Firm-level studies suggest that larger firms tend to be more strategically inclined to adopt innovative practices *and* engage in collaboration as part of their innovation activity compared to their SME counterparts (Vossen, 1998; Xiaobao et al. 2013). This has been attributed to the established structure, high capital investment, high capability, experience, and risk management capabilities that tend to distinguish large firms from small firms (Berends et al. 2014; Hall et al. 2016; Van de Vrande et al. 2009). Capability constraints in SMEs tend to slow down their adoption of innovative strategies and technological upgrading (Rosenbusch et al. 2011; Saluja, 2012).

At a macro-economic level, weaknesses in innovation among smaller firms has led to concerns about a growing productivity gap between larger 'frontier' firms and smaller 'non-frontier' firms. (OECD 2015). Andrews et al. (2015) argue, in particular, that frontier

firms which are trading internationally increased their productivity by around 3.5 percent per annum over the period 2001 to 2009 compared to a 1.5 percent per annum increase in non-frontier firms. They argue that the difference in productivity growth is attributable to a lack of innovation in non-frontier firms, itself related to limited knowledge diffusion and collaboration. But, why is knowledge diffusion to smaller, non-frontier firms so limited? Here, we adopt an in-depth qualitative approach to explore the barriers to innovation and innovative collaboration in a group of smaller firms in two traditional manufacturing sectors. We build on earlier analyses which have emphasized informational and motivational barriers to collaborative innovation which arise due to limited and asymmetric information and lead to a lack of understanding of the capabilities of potential partners, their trustworthiness and/or their ability to structure an innovation partnership. Based on the supply chain partnership framework by Kim et al. (2010), and extending the work of Hewitt-Dundas and Roper (2017) on market failures in innovation collaboration, our objective is to explore three specific market failures, which may limit the extent of collaborative innovation. These market failures capture: (a) Firms' inability to identify or recognise the potential benefits which they might derive from collaborative innovation; (b) Situations where a lack of information is available for assessing the suitability and capability of potential partners; and, (c) Difficulty in assessing the trustworthiness of potential partners which may lead to a reluctance to engage in collaborative innovation.

Our analysis adopts a qualitative approach focusing on how decision-makers in two traditional, SME-dominated, manufacturing sectors – metal-forming and metal-casting - acquire and evaluate knowledge about the trustworthiness, capabilities and strategic orientation of potential innovation partners (Creswell, 2013; Maxwell, 2013; Starks and Trinidad, 2007; Tracy, 2013). The argument proceeds as follows. Section 2 presents a brief review of existing literature on innovation collaboration and barriers to collaboration in SMEs. Section 3 provides an overview of the case-study sectors. Section 4 focuses on data and methods and Section 5 presents the empirical findings. Section 6 summarizes the main conclusions and discusses the implications of findings for the industry sectors investigated and SMEs in general.

2. LITERATURE REVIEW

2.1 Innovation Collaboration along and beyond the supply chain

Notions of innovation differ and extend beyond new products and processes to encompass the development of new markets, new sources of supply and firm re-organization (Schumpeter 1934)¹. In each case, this implies the discovery, development, application, and exploitation of new knowledge to generate competitive advantage (Dodgson et al. 2008; Van de Vrande et al. 1986). Innovation may help firms to create a position of technological leadership in a market and generate first-mover advantages by pioneering new opportunities in the marketplace (Gunday et al. 2011). As such, innovation plays a pivotal role in firm growth, longevity, and profitability and is a distinguishing feature of fast-growing firms (Anyadike et al. 2009; Geroski and Machin, 1993; Schumpeter, 1934)². However, the extent to which any firm is able to appropriate the benefits of innovation is variable, focussing attention on both exploration and exploitation in the innovation process (Asheim et al. 2007; Crowley and McCann, 2018; Fisher et al. 2010; Hewitt-Dundas and Roper, 2011).

Theoretical perspectives on innovation emphasise the value of firms' internal and external knowledge resources as the basis for innovation, and the role of innovation in generating competitive advantage (Fey and Birkinshaw, 2005; Zack 1999). Where firms' internal knowledge resources are limited this may constrain innovation and the competitive benefits which firms can derive (Gunday et al. 2011; Hewitt-Dundas, 2006; Kratzer, 2017; Spithoven et al. 2012; Van de Vrande et al. 2009; Xiaobao, et al. 2013), an effect which can be ameliorated by the development of collaborative innovation relationships (Cooke and Morgan, 1998; Laursen and Salter, 2014). This has led to recommendations that organizations should adopt collaborative or 'open' approaches to innovation strategy (Spithoven et al. 2012; Cassiman and Veuglers, 2002; Chesbrough

¹ The Oslo manual defines innovation under two categories; product and business innovation (OECD Oslo Manual 2018). Product innovation refers to a new or improved good or service; business innovation is the implementation of a new process or workplace function. In both cases, the outcome of these activities or the activities themselves must significantly differ from previous processes and products prior to the innovation taking place.

² This is emphasized by the positive relations between firm innovation and productivity performance (Crepon, Duguet and Mairesse 1998 and Niu 2014) even across a range of European economies (Crowley and McCann 2018).

2003, 2006), with evidence indicating that firms are already in transition to more collaborative approaches to innovation (Chesbrough 2003; Poot et al. 2009). Collaborative innovation may involve knowledge transfer both into ('exploration') and out of ('exploitation') the firm (Lichtenthaler 2016) creating 'purposive inflows and outflows of knowledge to accelerate internal innovation and to expand the markets for external use of innovation respectively' (Chesbrough et al. 2006, p. 1). Studies have also suggested that small firms may benefit more from external collaboration than larger firms, with this relationship being stronger for links within the supply chain (Vahter et al. 2014).

The nature of firms' external relationships may differ significantly, however, depending on the character of the external partner, the nature of the knowledge being shared. A standard distinction is that between collaboration within the supply chain with either customers or suppliers and 'horizontal' collaborations with competitors or other knowledge sources outside the supply chain such as universities. Supply chain capital which integrates structural relationships with relational capitals such as trust may enable firms to engage in open and long-term innovation relationships (Autry et al. 2008). On the other hand, links to non-supply chain actors such as universities may facilitate access to leading edge knowledge for innovation not available elsewhere (Hewitt-Dundas et al. 2019) or help firms access otherwise unavailable resources (Bakhshi et al. 2009). Relationships with different types of external partners may also drive different types of innovative activity. Econometric studies demonstrate strong links between supplier linkages and process innovation (Ganotakis and Love, 2012), customer linkages and product innovation (Mansury and Love, 2008) and consultants and organisational change. University linkages provide particular advantages where firms are seeking to develop new to the market innovations (Hewitt-Dundas et al. 2019).

2.2 Innovation Collaboration Barriers in SMEs

A firm's propensity to innovate, and the type of innovation strategy it adopts, is strongly influenced by a range of firm-level factors such as firm size, ownership structure and export status (Heimonen, 2012; Hassan et al. 2013; Parida et al. 2012; Terziovski, 2010; Tether, 1998, Varis and Littunen 2010 and Crowley and McCann 2018). Sectoral structure, dynamism and the character of sectoral appropriation regimes may also shape the ability and willingness of firms to adopt collaborative innovation strategies. Sectoral structure may shape the availability of potential innovation partners (Hewitt-Dundas 2012). Evidence on the effects of sectoral dynamism is mixed with some studies

suggesting a positive influence on the propensity for collaborative innovation (Gassmann and Chesbrough 20009, Parida et al. 2012 and Levinthal and March 1993) while other studies point to an opposite effect or no influence (Keupp and Gassmann 2009, Lichentahaler and Ernst 2009 and Chesbrough and Crowther 2006). Appropriation regimes linked to the strength of intellectual property (IP) protection may also be important, although again the evidence is mixed for firm-level openness with some studies suggesting that a strong focus on appropriability and IP protection can have negative implications for openness by limiting the potential for knowledge exchange in the innovation system (Almirall and Casadesus-Masanell, 2010; Bessen and Maskin 2009; Chesbrough 2003; Enkel et al. 2009; Oakey, 2013; Von Hippel, 2005). Other studies suggest a positive link between IP regimes and innovation (Baum et al. 2000; Chesbrough 2006; Laursen and Salter, 2014; Lichtenthaler, 2010; Teece 2002). The technological nature of sectors may also influence the propensity for collaboration. In manufacturing, collaboration may be more important (Gunday et al. 2011) as innovation is more often technology-driven and highly capital intensive (Van de Vrande et al. 2009).

For SMEs, the challenges of implementing collaborative innovation strategies differ from those faced by larger firms (Vossen 1998 and Xiaobao; Wei and Yuzhen 2013). SMEs typically have a distinctive governance structure characterized by organizational flexibility, less bureaucracy, superior market responsiveness in introducing product/service innovations (Spithoven et al. 2012), and a knowledge base derived from experience or learning by doing rather than structured R&D investments (Fernandez-Esquinas et al. 2017; Hirsch-Kreinsen, 2008; Terziovski, 2010). SMEs may, however, face resource and managerial capacity constraints which hinder both the development and exploitation of innovations (European Commission, 2018; Heimonen, 2012). Resource limitations may mean that SMEs have narrow products/services ranges, low-risk tolerance face difficulties in achieving economies of scale on input purchases, and in taking advantage of market opportunities that require large investments and production quantities (Gronum et al. 2012; Okello-Obura and Matovu, 2011). Furthermore, a lack of capital and difficulty in assessing commercial lending may restrict SMEs' ability to take advantage of opportunities or innovations that can lead to improved competitiveness (Haron et al. 2013; Van de Vrande et al. 2009). SMEs' managerial capacity may also be more limited, restricting their capacity to learn interactively and engage in collaborations with supply chain partners, research centres and other learning institutes (Fernandez-Esquinas et al. 2017). Together these constraints tend to slow

down the adoption of innovative strategies that can generate productivity gains in SMEs – the collaboration paradox (Rosenbusch et al. 2011 and Saluja, 2012).

2.3 Informational market failures and collaborative innovation

Kim et al. (2010) suggest there are four stages in the development of collaborations: identifying the strategic need for the collaboration; assessing and selecting partner(s); implementing the partnership; and, reassessing and reshaping the partnership. Each stage of this process to establish collaborative relationships requires information about the characteristics of partners and the potential value of the collaboration, a process which may be undermined where there are information gaps or failures (Hewitt-Dundas and Roper, 2018).

The first stage of the partnership development process envisaged by Kim et al. (2010) reflects firms' ability to appreciate the potential costs and benefits of any collaboration. In terms of innovation collaboration, this may reflect the uncertainty of the innovation process itself, risks linked to the effectiveness of any partnership as well as challenges linked to the appropriation of the benefits of any collaborative innovation (Asterbro and Michela, 2005). This assessment is likely to be more difficult for smaller firms due both to more limited managerial capacity as well as their more limited learning from prior innovation and innovation collaboration (Gkypali et al. 2019). Difficulties in assessing the costs and benefits of collaboration – the consequence of informational failures related to potential outcomes – may lead firms either to over or under-estimate the benefit-cost of collaboration. Prior evidence suggests, however, that firms tend to under-invest in collaborative innovation (Hewitt-Dundas and Roper, 2018)

The second stage in the process of establishing collaborations relates to assessing and selecting appropriate partners. This selection process can be challenging (Dyer and Singh, 1998) and requires detailed knowledge on the capabilities of potential partners and the extent to which these are complementary to the firm's own knowledge-base (Hoekman et al. 2010; Hosseini et al. 2017; Le Ber and Branzei 2010). Acquiring this type of knowledge may be more difficult where the geographical distance between potential collaborators is large or where potential partners are outside firms' existing networks (Berchicci et al. 2015). Views on the influence of geographical proximity are mixed with some scholars arguing that geographical proximity can be complemented or replaced by other forms of proximities (cognitive, organisational and social), and that it is not a necessary requirement for knowledge and innovation collaboration (Boschma,

2005; D'Este et al. 2012). Other studies have however emphasised the importance of geographical proximity as a key facilitator of knowledge exchange and collaboration (Balland 2012; Fantino et al. 2015; Laursen et al. 2011; Crescenzi et al. 2017).

Firms seeking collaborators may also face a dilemma in having to reveal some of their own technological or resource endowments in a bid to assess knowledge from a potential partner (Laursen and Salter, 2014). Where this involves revealing areas of product or technological strength there may be a risk of emulation by potential collaborators encouraging firms to adopt secrecy, legal exclusion rights and sometimes selective revealing as means of safeguarding innovation knowledge (Henkel et al. 2014; Henkel 2006). Conversely, revealing areas of weakness or knowledge gaps may alert competitors to potential market opportunities or bargaining opportunities.

Where information on the capabilities of potential partners is incomplete, limited or wrong this may lead to unsuccessful partner selection or the selection of inappropriate partners (Hewitt-Dundas and Roper, 2018). This second information failure relating to partner capabilities may lead either to collaborations not be undertaken or the formation of inappropriate partnerships (Le Ber and Branzei, 2010).

How much knowledge a firm is willing to share with its collaborators depends on the level of trust existing in the potential relationship and this, in turn, determines the mode of governance and the implementation of any collaboration (Aulakh et al. 1996; Hewitt-Dundas and Roper, 2017). In inter-firm relationships, trust defines expectations between partners and the fulfillment of obligations pertaining to the partnership (Madhok 1995; Thorelli 1986). Trust aligns closely with confidence and can be defined as “a firm’s belief that another company will perform actions that will result in positive outcomes for the firm as well as not take unexpected actions that will result in negative outcome” (Anderson and Narus, 1990 p. 45). Studies have shown that in inter-firm collaboration, besides the role of trust in deterring against opportunistic behavior (Bradach and Eccles, 1989) trust may also be important in limiting any temptation for partners to focus on deliverables outside the scope of the collaboration agreement (Heiman and Nickerson, 2004). Firms’ ability to assess the trustworthiness of potential collaborators defines a third informational failure which may lead either to the failure to establish or develop a collaboration or its effectiveness.

3. THE CASE-STUDY SECTORS

The metal casting (foundry) sector in the UK includes around 480 businesses catering primarily to the automotive, defence, engineering, infrastructure, and construction markets (Khan *et al.* 2017). The sector has contracted significantly over the last decade and currently employs around 16,000 people and has annual revenues of c.£1.9bn (Casting Industry Census 2017). The fundamentals of the metal casting process remain largely unchanged since the first recorded use of cast metals in Chinese statuary in around 600 B.C. (Salonitis *et al.* 2016 and Khan *et al.* 2017): molten metal is allowed to solidify in a shaped mould (typically made up of sand, ceramic, or steel) to yield the desired product (Khan *et al.* 2017). Hence, in a typical foundry, the manufacturing process is characterized by six stages; melting, alloying, moulding, pouring, solidification and finishing.

Despite being a traditional industry the metal casting sector has seen significant progress in its use of production technologies such as the use of simulation software, binder formulations, alloy development and high technology production machines (Thollander *et al.* 2013). Challenges remain however around energy efficiency, a lack of long term energy efficiency strategy, quality monitoring and assurance and issues with knowledge creation and management (Roshan 2014 and Thollander *et al.* 2013). These challenges are particularly evident in the smaller metal casting firms – often family-owned - which dominate the UK sector.

The UK metal-forming sector includes the manufacture of fasteners, pressings, and forgings. Comprising more than 400 firms, the vast majority of which are SMEs, the sector produces structural parts and components which make up substantial parts of automobiles, aircraft, machinery, propulsion systems, power generation systems, buildings and appliances (Ward, 2015). Metal-forming dates back to 4500BC and includes processes which typically involve the deformation of sheet or tube metals by external compressive forces or stresses. In metal forging, desired metal shapes are produced by placing a metal sheet or strip stock in between rollers, after which it is compressed and squeezed to the desired geometry (Yang, 2018). The forging process can be done at a high temperature (Hot Forming Process) or room temperature (Cold Forming Process). In metal stamping (also referred to as pressing), flat sheet metals are converted into various shape in a stamping press using techniques such as drawing, shearing or die cutting and forming (Choomlucksana *et al.* 2015). Innovation in metal-

forming focuses on specialized products using new metals and alloys and process optimisation and flexibility to compete with products made from less expensive metals and polymer materials (Misioleek, 2017; Neugebauer et al. 2011). Optimization is focussed on formability improvements, reducing tool and scrap percentages (Ramezani and Ripin, 2012), improving product strength-to-weight ratios and cost reductions (Galdos et al. 2017 and Chen et al. 2018).

4. RESEARCH METHODOLOGY

To better understand the influence of informational market failures on innovation collaboration we adopt a qualitative approach based on semi-structured interviews (Dasgupta, 2015; Tracy, 2013; Yin, 2017). An initial interview guide was developed based on a review of the literature on innovation collaboration, SMEs, market failures and the case-study sectors. This was followed by a pilot study, which entailed trialing the first draft of the interview guide on a company manager from each of the case-study sectors. The interview questions were also reviewed by senior representatives from trade associations in the case-study sectors. Feedback from this exercise ensured the clarity, relevance, and accessibility of the interview questions. Fieldwork was conducted in partnership with two trade associations for the case-study sectors; the Cast Metals Federation (CMF) and the Confederation of British Metal Forming (CBM) with interviews undertaken between May and August 2018.

A purposive sampling strategy was employed. Purposive sampling, although characterized by small sample size, engages respondents based on their in-depth knowledge of the topic (Creswell, 2017; Kumar, 2019; Zikmund et al. 2010). Firms registered as members of the CBM and CMF were notified of the research study, and participation requested. Thirty-two firms signified initial interest, of which twenty-five committed to participate in the interview process (13 foundries, 8 metal forming firms and four suppliers to both sectors). The firms interviewed varied in size including eight small firms (10 to 49 employees), 12 medium firms (50 to 249 employees) and five large (more than 250 employees) firms³. Interviewees were experienced CEOs, Managing Directors,

³ Previous research has highlighted the influence of firm size on innovation efforts (Van de Vrande 2009). The inclusion of large firms and suppliers was to allow a comparable study outcome as well as provide a comprehensive overview of innovation practice and perception in the industry sectors.

and high-level managers working across roles focused on innovation, R&D, business development, market expansion, and product and process development. Theoretical saturation occurred within the first fifteen interviews at which stage, responses from respondents were being replicated (Bowen, 2008; Guest et al. 2006). Basic meta-themes were already emerging after the first eight interviews.

Our analytical approach was guided by Nowell et al. (2017) and Thomas's (2006) outline for conducting a rigorous and relevant thematic analysis (see also Boyatzis, 1998). Data collection and analysis was done concurrently and all collected data was transcribed, cleaned and read repeatedly prior to the analysis. The interview transcripts, literature and research questions were iteratively consulted all through the analysis stage. We adopted the template approach (Crabtree and Miller, 1999; King, 2012) in developing 'a priori' codes for organizing and summarizing themes from the transcript. This coding template was created prior to a detailed evaluation of the transcripts via an iterative exploration of literature and the research questions (Taylor and Gibbs, 2010). The coding template evolved throughout the analysis as codes were modified as required or disregarded.

5. EMPIRICAL RESULTS

5.1 Understanding the benefits of innovation collaboration

We anticipate that due to incomplete information firms – particularly smaller firms – may find it difficult to accurately assess the benefits of collaborative innovation and may therefore either not engage in collaborative behaviour or engage in low levels of collaboration. To examine the influence of this market failure we explored how respondents perceive innovation as a concept, its meaning, description, and adoption in business.

Participants were aware of and broadly endorsed the importance of innovation and its benefits. All participants stated that their firm had at some point engaged, and in many cases were still engaging, in innovation. Five main notions of 'innovation' were suggested by the interview responses. These were: the creation of new products, novelty or finding a new alternative, significant step-change, solving problems and technological breakthrough. 'Significant step change', 'solving problems' and 'finding new alternatives for product and process improvement' were the most commonly cited definitions by participants in the metal casting sector. For example:

Participant 3A, “... solving problems, if you’re innovative you’re either coming up with a product which is better than somebody else’s product because it solves a problem or you are looking at your process and you’re trying to do things differently to solve a problem.” (R&D Manager in a medium-sized metal casting company)

Participant 10A, “Achieving technical improvements, pushing the boundaries of what processes are capable of, improving technologies that are already existing.” (Executive director of a medium-sized casting company)

The majority of participants in the metal forming sector defined innovation as ‘finding new alternatives’. For example:

Participant 6B, “... creation of new parts, new machines, expanding into the unknown. We use our initiative and a bit of imagination to try and design something different that somebody else can't design...” (Director in a medium-sized metal forming firm)

For suppliers, innovation involved ‘the creation of new products’ and ‘technological breakthrough’, viz.

Participant 13A “Innovation for us is new products and improved performance for other products. So, generally consistently improving our products for the customer with better benefits.” (R&D Manager of a small-sized firm, Supplier)

Notions of ‘innovation’ also varied with firm size. The majority of medium-sized firms (50 – 249 employees) defined innovation as ‘significant step change’ and ‘technological breakthrough’. However, in small firms (10 – 49 employees), innovation was seen as ‘the creation of new products’ and ‘finding new alternatives’.

A range of motivations for undertaking innovation was suggested by participants. Spreading risk, customer demand and market expectation, process improvement, growth and sales and remaining competitive were the most commonly cited motives. Remaining competitive and spreading risk emerged as the most mentioned innovation motivators in small firms, while customer demand and market expectation were cited most frequently by large firms. For example:

Participant 19A, *“Innovation! It is the only reason we are here...”* (Managing Director of a small metal casting company)

Participant 3B *“What’s actually happened since 2008/2010 when we had the enormous recession is that we decided to change the strategy of the company quite significantly really to try to get into manufacturing products.and find ourselves these niche markets all the time, to try and give us more protection from our competitors, so that’s why you’re always looking to try and innovate wherever we can.”* (Director of a small metal-forming company)

Participant 20A, *“Innovation is absolutely critical, we have to demonstrate to our customers that we are looking at new ways of doing things as well as looking at advancements in terms of what we can deliver in terms of process and in terms of productivity and our development.”* (Managing Director of a small metal casting company)

In medium-sized firms, meeting customer demand and firm growth were the leading motivations for innovation. One respondent commented:

Participant 11A, *“without innovation, you can't compete on price, as it were, so you've got to compete in different ways, through technology and offering something different.”* (Business Development Manager in a medium-sized metal casting company)

Turning to ‘how’ firms innovate, participant responses suggested seven predominant innovation practices (Figure 1). In-house R&D was the most frequently adopted practice across the case-study sectors with the majority of participants stating that this was the main driver of their innovation. Customer involvement, supplier involvement, and R&D outsourcing were also cited by study participants as current innovation practices. For example:

Participant 21A, *“...we have a small team and our R&D is just in-house. We have quite a number of clever people here, so we make up the R&D team.”* (Site manager in a small-sized metal casting company)

Participant 4B, *"We do not design, we do not have our own product. That makes a big difference. So we are reacting to what the customer wants." (Managing Director of a medium-sized metal-Forming Company)*

Supplier and customer involvement in innovation efforts were emphasized as common practice in medium and small firms while R&D outsourcing is a characteristic practice of large firms. Respondents commented:

Participant 5A, *"When it comes to innovation; I mean obviously a lot of it comes from the customer. The customer has a requirement and, and we develop that requirement, we don't design castings but we will certainly work with the customer to optimize the design, to make it castable and manufacturable." (Technical Manager in a metal casting company)*

Participant 10A, *"Suppliers, play a key role in terms of developing innovative new technologies and applying them to what we are doing here, and we have been pretty effective in dealing with suppliers." (Executive director of a medium-sized casting company)*

There was no evidence of innovation collaboration with other firms within either industry sector. Participants emphasised that collaborating with another firm manufacturing similar products was not realistic as market survival depended on originality and to a high extent, a level of competitive edge over other firms. As a result of this, firms tend to be secretive and do not share their expertise. According to respondents from the metal casting sector, this barrier has historical overtones and is a characteristic feature of the industry. However, responses confirmed the existence of a range of other innovation partnerships with universities, research centres, trade associations, etc. with a focus on accessing expertise and knowledge not found within the firm. For example:

Participant 4A, *"We're actually in partnership with universities as well, so we are currently in partnership with two universities at the moment, looking at robotics and automation." (Technical Manager in a medium-sized metal casting company)*

Participant 8A, *"We do some collaboration through the trade association championing health and safety group so that we can keep everybody safe, we're very open with sharing practices there." (Managing Director of a medium-sized metal casting company)*

Participant 3B, "... we have used consultancy services to help us with technical matters that maybe we didn't quite understand or we didn't have the internal resource to be able to deal with it." Director of a small-sized metal-forming company)

Collaboration within the supply chain was cited as the most beneficial form of interaction across both industry sectors. For example:

Participant 2B, "We work with different material grades, high strength alloys, and minerals, so we are continuously collaborating with our customers and our suppliers." (Director of a small-sized metal-forming company)

Firms reported a range of benefits from engaging in innovation collaborations. Improved processes and products, improved productivity, increased capability, customer satisfaction, new knowledge and development of new products were the most commonly cited potential benefits:

Participant 9A, "The benefits are the labour-saving and consistency of operations because now, whereas you needed to have two people to run the machine, now you only need one person to run the machine." (Financial Controller of a medium-sized metal casting company)

Participant 3A, "We might benefit from a bit more collaboration. because if we are good at making something and someone down the road is very bad at it but they're still exporting then does that give the UK a bad name or, whereas if everyone's very good then everyone says, go to the UK it's the place to be..." (R&D Manager in a medium-sized metal casting company)

Participant 5B, "...you get the benefit of 30, 40, 50 years experience immediately, without having to go through 50 years to get the knowledge, you get to take it immediately." (Director of a medium-sized metal-forming firm)

Nine main factors were identified as preventing firms from engaging in innovation collaboration (Figure 2): risk, firm size, time constraints, trust, IP ownership, knowledge,

availability of fund, corporate culture, and competitive environment.⁴ Of the nine main identified factors, market competitiveness was the most frequently cited barrier to innovation collaboration. Where respondents indicated that trust is important for any collaboration to occur the duration of relationships was seen as important with trust being built up over time. New relationships were seen as having some initial risk. Recourse to Non-Disclosure Agreements (NDAs) is common practice in managing such risks, however, this was deemed fallible and therefore, does not completely eliminate the risk factor. Financial constraints and limited managerial resources due to small size also emerged as barriers to innovation collaboration. One firm commented:

Participant 3A, “...as an SME, time, money, resources, brainpower you know, they are all working against us.” (R&D Manager in a medium-sized metal casting company)

5.2 Understanding the suitability and capability of potential partners

Insufficient knowledge of the capabilities of potential partners is a deterrent to collaboration. Firms’ openness is often limited by information flows:

Participant 19A, “They don’t like to tell you nothing. Up until really recently, if I went to another foundry I would not be allowed to walk around because I am a foundry-man..... So, would I work in collaboration with other companies? I would love to, but I can’t find anybody that particularly wants to collaborate with us.” (Managing Director of a small-sized metal casting company)

Participant 3B, “The sector we are involved in is fiercely competitive and nobody really wants anybody else to know what they are doing. It’s a major constraint to having any kind of partnerships.” (Director of a small-sized metal-forming company)

Participant 5A, “You certainly need to know a bit about what their business is, and that would definitely be an influencing factor really as to whether that would be the right partner or not if you’ve got a choice of course..... Yes, I think when a problem

⁴ Other factors mentioned by respondents included insufficient government support, concepts non-existent, skills, proximity and the technical-academic gap.

comes, it's not the first thing we think of.” (Technical Manager in a small-sized metal casting company)

All but one respondent suggested that knowing more about potential partners' firm's expertise, reputation, business strategy, and past projects, would act as a stimulus for collaboration. However, respondents emphasized the difficulty of obtaining this sort of information as firms are secretive. A technical manager in a medium-sized metal casting company stated:

Participant 5A, *“I mean we get to know enough about people, we know very little about a lot of the potential collaborators we have had in the past.It is a bit like speed dating, you find them in an event, you swap business cards, you go and have a meeting.So would it influence our decision to collaborate? No! That is what, if the concept of a collaborative venture is agreed then you go and find out who your partners are and you tend to make that work. It tends not to be the other way round.” (Technical Manager in a small-sized metal casting company)*

Similar sentiments were echoed by other participants:

Participant 21A, *“... I guess you do not always know what people can do. There is a company called XYZ doing all the printing and mould and I did not know what they could do. Then I went to their facility and saw all their machines and they have newer bigger machines. It was more of an eye-opener and you can see what's available and what they can do.” (Site Manager in a small-sized metal casting company)*

Participant 11A, *“....knowing more about capabilities is important. I mean often you do not know exactly what such a partner may be able to offer or what technology or understanding or knowledge they may have behind them. So I think the more information you have up front, the better equipped you are to make a decision as to whether that's something or a route you want to go down.” (Business Development Manager in a medium-sized metal casting company)*

Participant 3B, *“Knowing about capabilities is crucial. It goes back to something that is common across firms in the sector, you don't really know what they're up to or what kind of things they're working on. So you can not make a judgment as to*

how relevant it might be, for us to try and engage with them.” (Director of a small-sized metal-forming company)

Where it was accessible, information about the capabilities of potential collaborators came from exhibitions/conferences, internal research, supply chain partners and trade associations (Figure 3). Supply chain partners and trade associations were seen as particularly important knowledge brokers as they tend to have a more comprehensive knowledge of the capabilities of individual firms. Respondents commented:

Participant 7B, *“Within the industry, with the different sectors, we get a lot of literature sent to us of what is new. So we are constantly reviewing, you know, what’s out there either by search engines or by exhibitions.” (Director of a small-sized metal-forming sector)*

Participant 10A, *“I suppose exhibitions and conferences are pretty good. Trade journals, word of mouth, through networks like CMF, they would be our main sources of information.” (Managing Director of a medium-sized metal casting company)*

Participant 8A, *“So I think when you’ve got a supplier that has got a range of technologies, seeing all of it in one go is the right way to digest it and understand exactly how you can use them.” (Managing Director of a medium-sized metal casting company)*

Respondents identified five main types of information which would be useful about potential collaborators: product and process type, quality standards, reputation, technological capabilities and past projects. Understanding potential collaborators’ product and process type were seen as useful in ensuring strategic alignment. Also, a good knowledge of a potential collaborator’s quality standards, competences and certifications were seen as important in ensuring partners’ commitment to quality standards and assurance. Participants also cited reputation as important. References from trustworthy sources within the business community as well as friends and family were seen as important reference points. Respondents commented:

Participant 7B, *“we would need to know who they are, what sectors they have worked with and we would need to know if they were dealing with anyone that*

might be a conflict of interest to what we were doing.” (Managing Director of a small-sized metal-forming company)

Participant 19A, “...understanding their process would reveal what they need. Now, that means they've got to let us in ...so we can, in detail, look at what they're doing and see where we could work together to solve something that we both need.” (Managing Director of a small-sized metal casting company)

Participant 10A, “We would probably judge that confidence in terms of their experience. Talking to other people that had worked with them, or seeing evidence of other projects they had done... like case studies of previous projects.” (Managing Director of a medium-sized metal casting company)

5.3 Understanding the trustworthiness of potential partners

Trust is a key determining factor in the decision to pursue or pull back from any form of business relationship. All participants indicated that for any form of collaboration there has to be some level of trust. Across the sectors, the use of NDAs (Non-Disclosure Agreements) are common and these are adopted to ensure that collaborative firms do not give away confidential information. This is especially useful when the collaboration is in its infancy. Participants also indicated that there is always some element of risk in collaborations: ‘the trustworthiness of partners can never be fully ascertained and often depending on one’s gut feeling is therefore necessary’. Some participants cited instances where this had gone wrong and led to unfavourable outcomes because a collaborator did not keep their part of the deal.

Respondents also indicated that trust has to be established on a personal level - it depends on the personal relationship with individuals in collaborating firms – and this takes time to establish. Respondents commented:

Participant 19A, “...and there has to be that trust. With trust then comes the more, with the more comes more trust if you see what I mean....It is a spiral that builds... So there has to be a lot of trusts.” (Managing Director of a small-sized metal casting company)

Participant 23A, “I think you have to go into these things with a degree of trust but it’s, it’s clear that sometimes individuals within collaborations can matter.

Individuals within the teams can matter, so it is important that trust is established on a personal level.” (Technical Director of a large metal casting company)

Participant 6B, *“Yes, definitely, trust is very important because I wouldn’t like my contact to give my idea to somebody else because we could potentially lose the business. So trust is very important, this is why NDAs come into it.” (Director in a medium-sized metal forming firm)*

Participants identified eight ways in which potential partner’s trustworthiness is assessed; relationships, assessments, reputation, recommendation, willingness to protect data, NDAs, financial stability and willingness to protect data (Figure 4). Of the eight trust measurement techniques, relationships, use of NDAs and reputation were most frequently mentioned by participants. Meeting and building a relationship was the most widely adopted technique for assessing trustworthiness across respondents. According to respondents, it forms the backbone for any form of long-lasting business relationship. This is because it can either “*make or mar*” the development of a potentially beneficial relationship. It is the first step to “*breaking the ice*” between firms and based on the initial perception of firm representatives at the meeting, a decision on trust is made. One respondent commented:

Participant 20A, *“For me personally, going to meet them individually and gauging from their personality. I suppose within our industry, you were almost able to find somebody who could refer. So yes, I think the main one would be face-to-face.” (Managing Director of a small-sized metal casting company)*

Respondents also indicated that conducting audit assessments and visiting firm sites prior to and during business engagement especially on the supply side is basic industry practice that has proven useful in assessing trust. Assessing trust in this manner enables the establishment of rapport as well as providing a mechanism for building a better understanding of processes and services offered. One respondent commented:

Participant 2B, *“We visit and conduct assessments around the facility, especially with our suppliers, the kind of standard things really.” (Commercial Director of a large metal-forming company)*

How financially viable a potential collaborator is, also plays a role in how it is perceived in the context of trust. Respondents indicated that prior to any form of collaboration,

especially for major projects, financial checks are conducted to establish the financial standing of the other firm. This is done to ascertain that the firm can be trusted before making financial commitments to such business partnerships. This is also necessary to ensure that the other party was not “*biting off more than it can chew*” and has the financial standing to see the project through.

The use of NDAs facilitates the setting up of a formal agreement between collaborating firms by preventing the leakage of confidential information or technical know-how. Respondents mentioned that this is adopted in many if not all of their business engagements and this includes across the supply chain. Building on trust from this point onwards then relies on how both parties proceed in the partnership, coupled with experiences and lessons learned. Despite the legality surrounding NDAs, respondents iterated that sometimes, it does not act as a deterrent to some firms breaking the confidentiality pact and disclosing information. Openness to communication is seen as an indication of trustworthiness. Respondents talked about this in two contradictory ways. Openness to sharing information can be a plus, showing that the firm is ready to engage and is transparent in its business dealings; sharing data openly may also imply, however, that the firm cannot be trusted with confidential information.

The kind of image or value system a firm portrays or is known for also influences how a firm is perceived as being trustworthy or otherwise. The reputation of a firm according to respondents is reflected by, and is largely a product of, its interactions across the business community, supply chain, community, and in the public domain. Relying on this as one of the ways of measuring trustworthiness is usual practice in the case-study sectors. Respondents indicated that conducting detailed research on a potential collaborator could be done via internet searches, business networks, trade associations, and other available information sources. Similar to reputation, respondents take into consideration recommendations and references from business networks, friends and family in assessing the trustworthiness of a firm:

Participant 5B, “Also their openness in sharing information and data with us is very important....It would show that they take it seriously, they're protecting their data, then you would feel they could protect yours.” (R&D Manager of a medium-sized metal casting company)

Participant 11A, “It is through open dialogue, so sharing of information to start off with before even a collaborative framework is put into place... is how open they

would be to sharing information with us.” (Business Development Manager of a medium-sized metal casting company)

A firm’s trustworthiness is also assessed by its willingness to protect data and most especially IP. This was raised as a particular issue when collaborating with universities who experience a tension between seeking recognition for their activities and preserving confidentiality.

6. DISCUSSION & CONCLUSION

This study has explored the views and experiences of firms in the UK metal casting and metal forming sectors on specific market failures which may hinder the extent of collaborative innovation. The results emphasise the difficulty of collaboration in competitive markets and identify a number of informational gaps which may shape the collaboration paradox.

Innovation itself is seen as important for sustaining competitiveness with firms also noting the need to spread risk, increase sales revenue, improve processes and meet customer expectations. Interestingly, most of those interviewed linked innovation to their position in the supply chain suggesting a link between innovation and business strategy (Teece, 2010). Respondents are also aware of the benefits of innovation collaboration although a clear hierarchy of strategies emerges with many firms only engaging in internal R&D, tending to keep their innovation within the boundaries of the organization. Where the knowledge necessary for innovation was not available, or could not be developed internally, firms engaged in collaborations with customers and suppliers. Indeed, many of the participants viewed innovation collaboration with customers as crucial to improving sales and maintaining their customer base (Flynn et al. 2010; Oke et al. 2013). Where supply-chain collaborations could not provide the necessary knowledge firms were also collaborating with universities, trade associations, and research institutes. However, we found no evidence of inter-firm collaboration within the individual industry sectors. That is, firms did not collaborate with each other at the innovation level. Many of the respondents indicated that the practice was simply non-existent in the industry sectors. The main reason for this non-practice was attributed to competitive markets. Thus, firms perceived such collaboration as posing a risk to their competitive edge and performance. This indicates that competition is a factor that deters innovation collaboration between firms (Reed et al. 2012).

Some firms were reluctant to engage in innovation collaborations for a number of other reasons. One of these is risk. Many respondents indicated that they would rather invest in an already proven technology rather than a completely radical new idea that has not been proven and with the possibility of failing. Thus, preferring to invest within the boundaries of the “known” rather than the “unknown”. Risk as a barrier extends beyond a limitation to collaborative innovation, but rather a limitation for innovation more generally. Firms tend to weigh the investment for innovation as against the possible benefits or losses if the innovation does not yield expected benefits or is never introduced to the market. This cost-benefit analysis and the associated risk determines the innovation strategy of a firm and the approach to innovation. Where it would be expected that sharing the risk of innovation with a partner might be a motivation for innovation collaboration, findings from this study suggest otherwise. In addition, resource constraints, the size of the firm, IP ownership and protection, corporate culture, and time constraint, were all mentioned as barriers to innovation collaboration. These barriers are consistent and confirm past findings on the topic (Hewitt-Dundas and Roper 2018; Van de Vrande et al. 2009; Xiabao et al. 2013).

Our findings also indicate that a lack of trust or openness is a factor that discourages firms from engaging in innovation collaboration. Many respondents stated that there was a high level of secrecy and lack of trust across the case-study sectors, making it difficult for such collaborative relationships to occur. Trustworthiness plays a key role in the decision to collaborate. This confirms past findings on the role of trust in innovation collaboration (Hewitt-Dundas and Roper, 2018). Furthermore, respondents indicated that the lack of knowledge of the capabilities of firms across the sector was a hindrance to firms embarking on collaborations, confirming our second market failure. This barrier prevents firms from utilizing available knowledge and creativity from other firms, as there is a lack of awareness of the various possibilities that are available and can be harnessed.

Knowledge of the capabilities of a potential partner was further explored in our second research question. This evolved how insufficient information on capabilities influenced the decision to collaborate. Our findings indicate insufficient information on a potential partner deters firms from collaborating, thus confirming findings by Hewitt-Dundas and Roper (2018) on market failures and OI. Firms that know more about a potential partner may decide to collaborate. Indicating that, knowledge of a potential partner’s capabilities has a positive influence on the decision to collaborate. Supply chain partners are an

important information resource in this regard. This is because supply chain partners, especially suppliers tend to be knowledgeable about the capabilities of many other firms in many sectors because of their role in the supply chain, which affords them the opportunity to interact with a vast array of firms within and outside the industry sectors. Similarly, trade associations due to their role as an overseeing body for specific industry sectors tend to know about what member firms do and their processes. Although the level of information accessible to trade associations is largely dependent on what the member firm wants them to know, it however still serves as a good starting point for knowledge of capabilities.

Our results also show that specific information such as product and process types, quality standards, reputation, what can be offered and past projects are important in helping firms to make a decision to collaborate. Firms indicated that knowledge of these is important to determine if further discussion is necessary or not. Thus, where knowing more can potentially lead to the possibility of a collaboration, it also can lead to negative outcomes such that discussion on collaboration is not explored further and the alliance fails to proceed.

Finally, our findings also confirm the influence of the lack of knowledge of a potential partner's trustworthiness as a limiting factor on the decision to collaborate (Hewitt-Dundas and Roper, 2018). Results indicate that trust is essentially important in the decision to collaborate (Madhok, 1995). There was a common consensus across all participants with regards to trust being crucial to collaboration consideration. Our findings show that knowing more about the trustworthiness of a potential partner can positively influence the decision to collaborate. Being able to trust a potential partner was deemed more important than setting up NDAs and contractual agreements (Connelley et al. 2015; Wang et al. 2008). There is however also a level of risk when taking the first step towards collaboration as the majority of respondents indicated that trust grows over time and develops as a relationship is built. Thus making many firms stay on in relationships with long-term business associates such as supplier relationships as they are often reluctant to engage new firms for "fear of the unknown" and inability to take the first "leap of trust".

Evidence from elsewhere suggests that, in general, levels of investment in innovation (Arrow, 1962) and innovation collaboration (Hewitt-Dundas and Roper, 2018) are below the social optimum. Competition and the risk of unintended knowledge leakage in innovation collaborations may naturally restrict intra-sectoral collaboration. However, our results suggest that both supply-chain partners and trade bodies can play a useful role

in helping firms to overcome other informational barriers to collaboration relating to potential partners' capabilities, motivations, and trustworthiness. Trade bodies, in particular, can act as 'honest brokers' within their sector, and policy initiatives could be developed to resource and strengthen this 'convening' or 'brokering' role. For example, Trade Associations are currently treated under special tax arrangements guided by the Lochgelly principle and outlined in the HMRC Business Income Manual (BIM24805)⁵. This allows members' contributions to be deducted in full from their taxable income while the Association complies with standard corporation tax rules on any commercial profits. Extending corporate Gift Aid rules – currently applied to Charities – to Trade Associations would allow Associations to develop their brokering and networking activities with significant potential benefits for collaborative innovation⁶. More direct supports could also be developed to help Trade or Industry Associations develop their brokering capacity and provide services as innovation intermediaries helping firms to establish and develop collaborative innovation. Such services can be cost-effective but depend on the careful alignment of funding mechanisms and objectives (Russo et al. 2019). There is also a need to recognise that innovations differ and Trade or Industry Associations may be better placed to help the diffusion of organisational and productivity related innovations rather than innovations based on proprietary knowledge. Issues may also arise with the capabilities of smaller companies in terms of forming and developing partnerships, suggesting that Trade or Industry Associations may also have a role in building capacity for open innovation.

Our analysis is subject to a number of limitations. First, despite drawing on a rich and detailed qualitative data set we understand that this represents an incomplete view of innovation collaboration among SMEs in general and limits the generalizability of our findings. Second, we focus here on firms' view of collaboration and do not yet take into account the perspectives of potential collaborators either along the supply chain or outside the supply chain. We aim to address both issues in a further study.

⁵ <https://www.gov.uk/hmrc-internal-manuals/business-income-manual/bim24805>

⁶ HMRC already maintain a register of Trade Associations to which the principles of BIM24805 apply so in administrative terms this type of regulatory change should be relatively low cost.

Figure 1: Innovation Practices

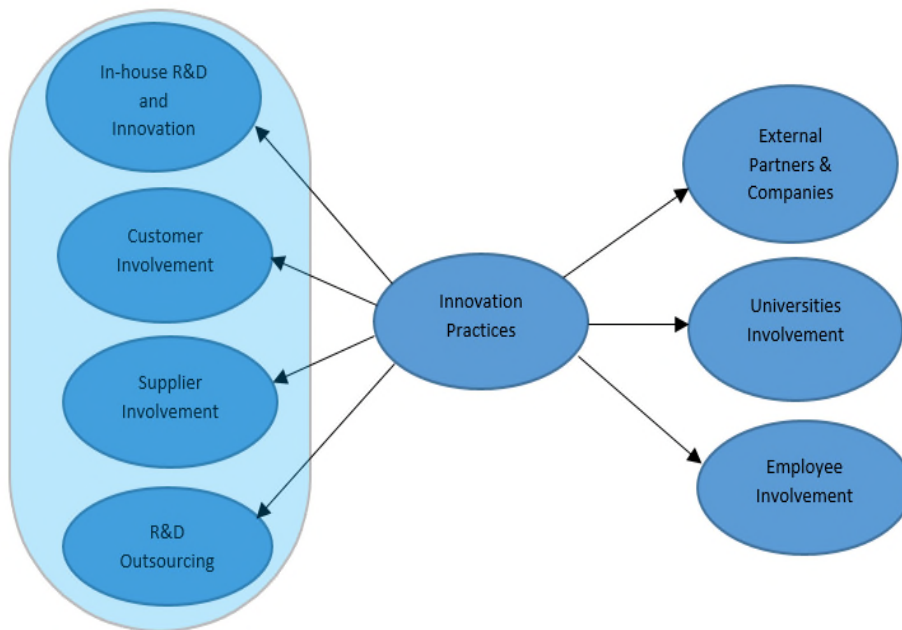


Figure 2: Barriers to Open Innovation



Figure 3: Partner capabilities which are important for the collaboration decision

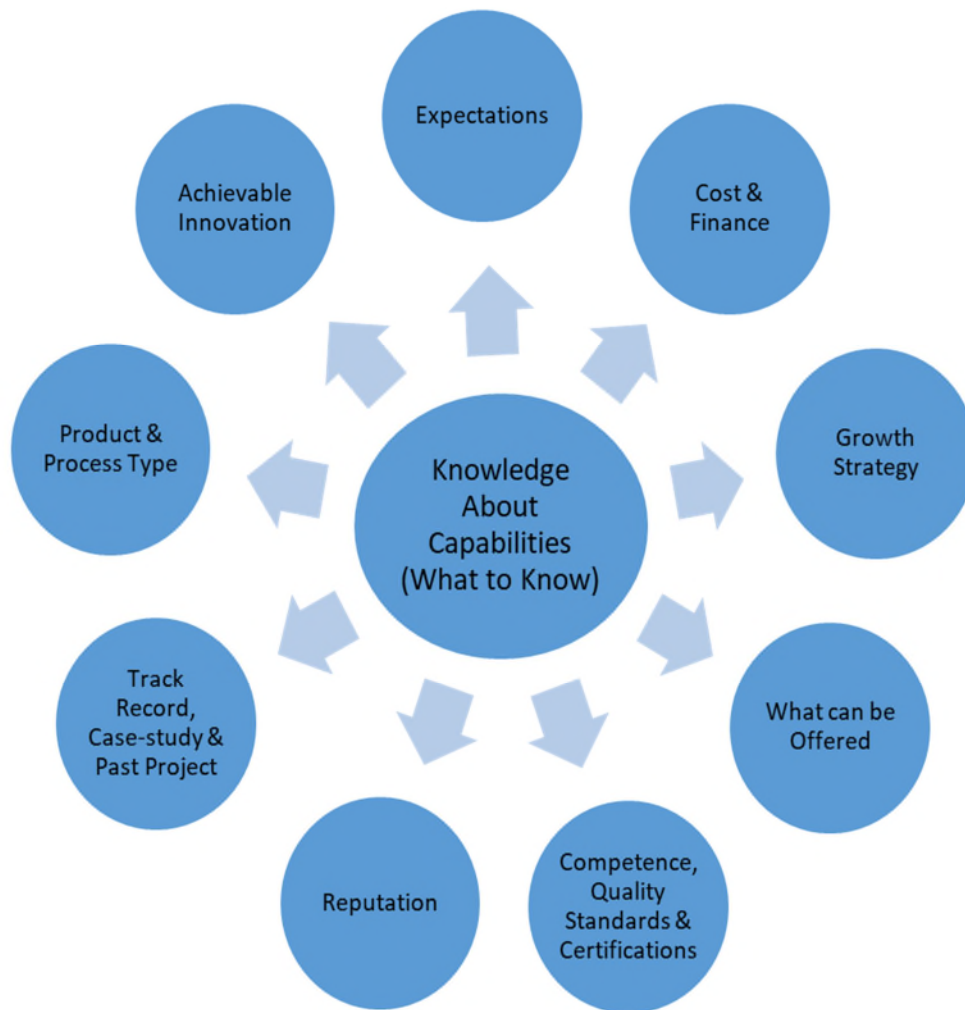
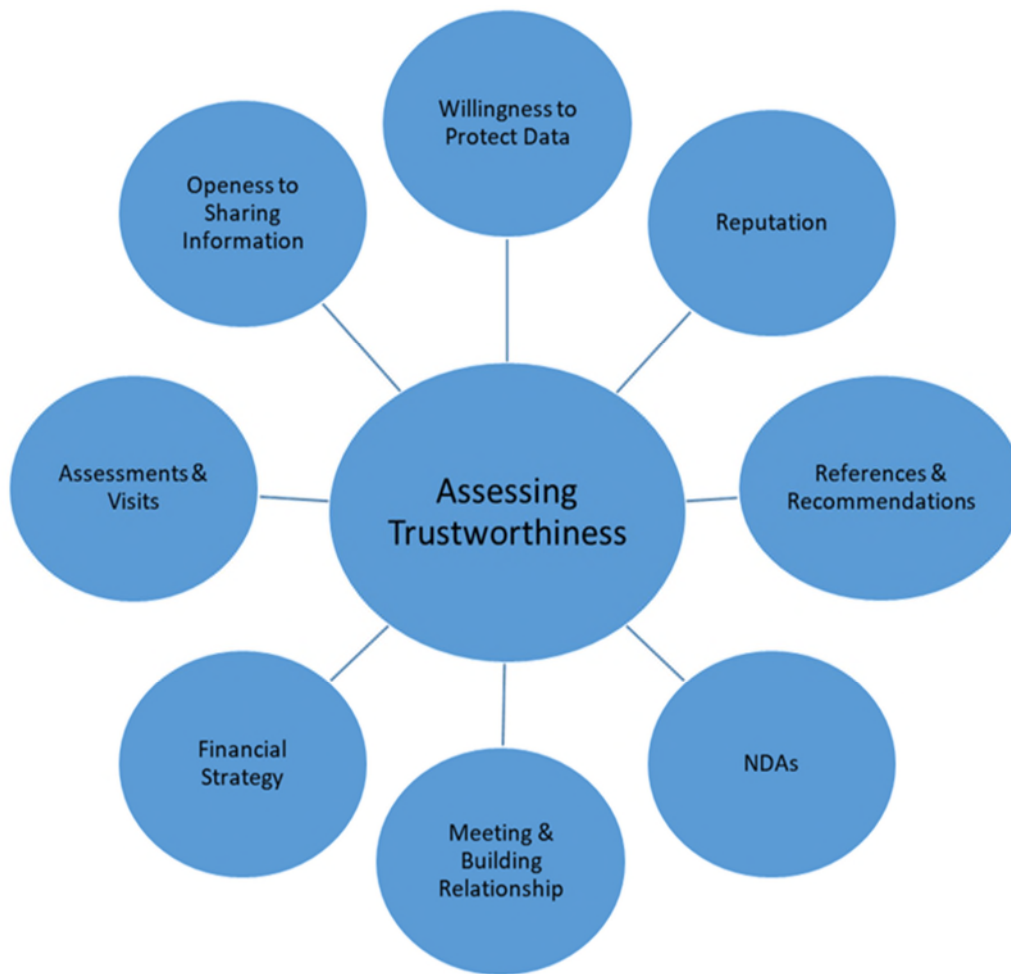


Figure 4: Techniques for Assessing Trustworthiness



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