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Limits to networking capabilities: Relationship trade-offs and innovation

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ABSTRACT

The capability of firms to leverage external network relationships strongly supports the development of successful new products and services. Network partners help to shape innovations and pave the road to commercialisation. Yet, despite this considerable knowledge about the importance of networks for innovation, we do not understand how firms embedded with multiple network partners manage competing priorities and associated attention trade-offs to maximise the full innovation potential of these relationships. Gaining insight into this deficit would serve to clarify networking capability theory and challenge its 'more is better' truism. To study this, we investigate Australian oil and gas firms' relationships with customers and suppliers, and trade-offs between these channels, to discover the impact upon innovation. We find that, while focused relationships within each channel (deep embeddedness) supports innovation, increasing vertical embeddedness with suppliers and customers simultaneously lowers firms' ability to introduce new products or services. Two findings emerge from our research: first, that there may be organisational limits to the attention span necessary to fully leverage the innovation potential of multiple network partners; and second that increasing vertical embeddedness may lock firms into non-innovative network positions. Findings indicate a strong need for attention-switching capabilities at the firm level.

1. Introduction

A robust networking capability is important to innovation in a business-to-business environment, particularly with regard to integrated products. These innovations involve sophisticated and complex blends of disparate technological knowledge and componentry provided by many specialist firms (Davies, Brady, & Hobday, 2007; Freytag & Young, 2014; LaPlaca, 2014; Storbacka, 2011). Delivery of new products or services in this environment involves being well-versed in network reconfiguration in order to address customer-specific requirements for new products (Mitrega, Forkmann, Ramos, & Henneberg, 2012; Ritter, Wilkinson, & Johnston, 2004).

Networks are important to innovation because they enable the exchange, transfer and recombination of new knowledge and ideas (LaPlaca, 2014). Networks are particularly good at supporting the communication of fine-grained and tacit forms of knowledge associated with new products (Jones, Hesterly, & Borgatti, 1997; Rost, 2011; Uzzi, 1997). For instance, strong customer networks help focal firms to clarify technology requirements, often via co-development partnerships (Ritter et al., 2004). Similarly, strong supplier networks have a multiplicative effect on the technologies that focal firms can draw upon to develop their own solutions (Davies & Hobday, 2005; Ritter et al., 2004). Evidence suggests that close-knit customer and supplier networks are particularly beneficial to creating new products and services in a range of integrated product industries, ranging from locomotives to telecommunication systems and commercial aircraft (Cacciatori, Tamoschus, & Grabher, 2011; Davies & Hobday, 2005, Davies et al., 2007).

However, there has been little consideration of the trade-offs or interactions associated with being involved in multiple connections in an industrial network. We use the attention-based view of the firm and lock-in theories to investigate these problems (Ocasio, 1997; Sydow, Schreyögg, & Koch, 2009; Whitley, 2002). In the attention-based view of the firm, managerial attention is seen as limited, both in direction and intensity (Li, Maggitti, Smith, Tesluk, & Katila, 2013; Ocasio, 1997). Instead of paying full attention to every potential network partner, firms exhibit attention patterns that are shaped by the particular problems that they face at that moment (Ocasio, 1997, p. 189). This may explain why firms that maintain multiple network connections struggle to maximise their innovation potential (Laursen & Salter, 2006). However, we also know that firms can overcome informational overload, that is, temper the ill-effects of attention deficits, by choosing to adeptly switch between different problems over time (Koput, 1997; Li et al., 2013; O'Reilly & Tushman, 2007). Thus, while we argue that

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network partners can serve different purposes at different times, and that attention switching enables this, it seems that this switching capability has not been explored in any great detail. It also seems that firms without the ability to switch become encumbered with multiple partners that they end up becoming a non-innovative cog in the network; conducting business by placating their supply chain to the detriment of their own innovative capacity. In other words, firms that are deeply embedded with multiple partners may be less likely to develop new products or services because their network partners prefer technological certainty and perceive innovation as threatening to their normal business activities (Whitley, 2002). To explore both of these drawbacks, we focus on vertical embeddedness with suppliers and customers: a factor which is known to be vital in developing innovations for focal firms (Fitjar & Rodríguez-Pose, 2013). Therefore, we ask: *Is there a trade-off between customer and supplier embeddedness in terms of product or service innovation?*

To address this question, we study the firms that are responsible for exploring and producing petroleum resources in the Australian upstream oil and gas industry. Exploration includes searching for geologically stored oil or gas resources, while production involves all the steps necessary to extract resources (Persaud, Kumar, & Kumar, 2003). With its origins in the 1860s, the upstream industry well exemplifies an industry that has a highly interdependent supply chain consisting of deeply embedded and long-term relationships between customers and suppliers, a structure that supports technological progress and innovation (Acha & Cusmano, 2005; Barlow, 2000; Crabtree, Bower, & Keogh, 1997; Perrons & Donnelly, 2012; Stinchcombe & Heimer, 1985).

The remainder of this document is organised as follows. The *Conceptual framework and hypothesis* section fully develops the conceptual framework and derives a set of hypotheses. The *Methods* section introduces the survey, sample and regression methods. The *Analysis and findings* section reveals the results of logistic regression models that show the relationship between supplier and customer embeddedness, and the trade-off between the two as they relate to new product or service outcomes. This section also includes a Latent Class Analysis (LCA), which aims to identify potential sub-groups of firms within the sample with different customer and supplier embeddedness profiles, describe differences among sub-groups by indicators of external engagement, and re-run the logistic regression models to ascertain whether or not the results are homogenous across the sample. The *Discussion* section discusses the implications of these findings. In the *Conclusion* section, we summarise our findings for theory and practice, identify the limitations of the study and suggest viable future research pathways.

2. Conceptual framework and hypotheses

2.1. Network embeddedness and innovation

The capability to leverage network relationships is fundamental to understanding how firms support different business projects and develop innovations (Freytag & Young, 2014; Mitrega et al., 2012; Wang, Zhao, & Voss, 2016). Network-competent firms combine relationships with different collaborators into new configurations to channel new knowledge into bespoke solutions for customers (Brusoni, 2005). Ritter and Gemünden (2003) refer to this as 'network competence', which is the capability to maintain and exploit inter-organisational relationships. They argue that this is a particularly strong predictor of product innovation success.

An important aspect of integrated solution industries is that their inter-firm networks, which arise from repeated interactions between firms to deliver new products, are relatively robust and remain stable over time (Ford, 1980; Håkansson & Ford, 2002; Mu, Thomas, Peng, & Di Benedetto, 2016). These types of firms often become deeply embedded in their networks because they serve inter-dependent roles in the production function of their industry (Cattani, Ferriani, Frederiksen, & Täube, 2011). Embeddedness between suppliers and customers (i.e., vertical embeddedness Halinen & Törnroos, 1998) is particularly vital to product innovation in these settings (Bouncken, Clauß, & Fredrich, 2014). This is because understanding each other's capabilities and resources in the context of new product development facilitates the collaborative creation of new business opportunities for both buyers and sellers (Fletcher & Barrett, 2007). Nowhere is the importance of vertical embeddedness more apparent than in business-to-business networks where more complex customer needs must be articulated and translated into sophisticated and specialised products (Bonner, 2010). In these settings, interactions between suppliers and customers become more frequent and the nature of the relationship is more intense. That is, innovation relies on two-way communication and team problem-solving to develop a solution that meets their individual needs (Bonner, 2010; von Hippel, 1994).

Increasing embeddedness has a positive impact on innovation, as clearly shown recently by Mu et al. (2016). They show that increasing levels of interaction with external parties relates directly to new product performance. Here, analysis of data from high-tech firms in China reveals a strong positive interaction between external networking *capability* and internally-focused networking *ability* (recombining knowledge and activities within the firm) to deliver successful new products. They also show that firms with high levels of market orientation and high levels of networking capability are more likely to have high-performing products. These findings reveal that increased levels of focus on network partners can relate strongly to innovation outcomes.

However, there is reason to believe that the relationship between embeddedness and innovation is not simply positive and linear. Instead embeddedness is likely subject to increasing returns to innovation, a construct that we refer to as deep embeddedness. Here, we consider deep embeddedness to be the increasing numbers of collaborations within a particular collaborator group (e.g., customers or suppliers). Firms that are deeply embedded are able to create new combinations of knowledge by drawing on collaborators' disparate capability sets, most likely through information heterogeneity. Such heterogeneity increases the probability that a solution can be found to an innovation problem by combining unique combinations of knowledge (Leiponen & Helfat, 2010). Such combinatory relationships can be understood simply by looking at the number of different two-firm combinations a focal firm can create. For example: four collaborators yield six unique combinations; eight collaborators yield 28 combinations; 16 collaborations yield 120, and so on. Combinations thus increase exponentially with a linear increase in collaboration numbers. This outcome is especially important in many project-based industries, because opportunities for innovation cannot be anticipated a priori (Acha, Gann, & Salter, 2005). Thus, innovation opportunities are contingent on project circumstances. Firms with a greater stock of collaborative resources (each with differing capabilities) injects novelty into these fleeting opportunities, thereby helping firms to innovate (Hobday, Davies, & Prencipe, 2005). Therefore those with greater combinatory positions stand to gain the most innovation potential.

The exponential relationship between deep embeddedness and innovation does not simply stem from innovation heterogeneity, but also from developing capabilities to manage these relationships. Capabilities around curating, maintaining and ending collaborations contribute to performance (Forkmann, Henneberg, Naudé, & Mitrega, 2016; Zaefarian, Forkmann, Mitrega, & Henneberg, 2016). We extend this argument by positing that deep embeddedness within specific collaborator groups enables greater innovation outcomes. A focus on the use and re-combination of resources within a collaborator group gives rise to this combinatory capability, which builds on itself. For instance, capable firms can quickly reactivate dormant relationships to create teams that can capitalise on the unique requirements of new innovation projects (Iacono, Martinez, Mangia, & Galdiero, 2012; Manning & Sydow, 2011). They can easily curate novel combinations of firms to address these requirements based on a shared understanding of each other's capabilities that has been developed through previous interactions (Bechky & Okhuysen, 2011; Taylor & Greve, 2006). The capability to do so improves innovation outcomes because, rather than spending time learning about each other, firms can use the shared understanding of roles and an increased capacity to integrate their shared resources to accomplish the project and develop innovative solutions (Bechky, 2006; Bechky & Okhuysen, 2011; Jones & Lichtenstein, 2008).

The next sections examine the impact of deep supplier and customer embeddedness, and potential trade-offs between them, in relation to product or service innovation.

2.2. Deep supplier embeddedness

Suppliers play an increasingly important role in the innovative activity of industrial firms (Luzzini, Amann, Caniato, Essig, & Ronchi, 2015; Pulles, Veldman, & Schiele, 2014). Very deep supplier relationships, typified by an intense focus on customers' specialised needs, contribute strongly to the innovation potential of the customer because innovative ideas and technological information are shared more freely. This supports the co-development of new products and process improvements (Pulles et al., 2014). To conduct their complex product development projects, customers, especially system integrators who combine disparate technologies into larger product systems, increasingly rely on such enduring and robust relationships with specialised suppliers (Cattani et al., 2011; Davies & Hobday, 2005; Hobday, Rush, & Tidd, 2000). Indeed, suppliers are often included in design and engineering teams as part of new product development initiatives in industries producing, for example, chemical products (Brusoni, 2005; Martinsuo & Ahola, 2010). Furthermore, the increasing modularity of complex products requires deep supplier relationships to assist buyers to integrate the subsystems they purchase. This, in turn, has resulted in the increasing prevalence of long-term, blended product and service contracts between buyers and suppliers (Brusoni, 2005; Davies et al., 2007; Gann & Salter, 2000; Geyer & Davies, 2000; Salunke, Weerawardena, & McColl-Kennedy, 2011).

In the oil and gas industry specifically, large supply chains represent an interdependent ecosystem of firms with varying levels of specialisation (Acha & Cusmano, 2005). These specialist firms work collaboratively on industry projects, and interrelate to develop technological advances that support the overall innovation process of the (Acha & Cusmano, 2005; Crabtree et al., 1997). Despite trends toward vertical integration in the largest companies, exploration, construction, and production still require a great deal of subcontracting to access a range of specialised firms (Barlow, 2000; Perrons & Donnelly, 2012; Stinchcombe & Heimer, 1985).

Empirical evidence confirms the positive effects of deep supplier embeddedness in integrated solution industries. For example, in the UK, construction industry suppliers seem to be highly important to firms that have introduced product innovations (Reichstein, Salter, & Gann, 2008). Similarly, Australian construction firms rely heavily on their suppliers to provide the complementary knowledge and skills necessary to overcome internal resource shortages and meet project-related innovation challenges (Manley, 2008). To explain this, Dubois and Gadde (2000) argue that having deeply embedded relationships with suppliers helps firms develop complementary knowledge which is linked to (and subsequently positively affect) their capability to develop new technology. According to Nieto and Santamaría (2007), the importance of supplier relationships is further supported in a sample of Spanish manufacturing firms in that, when promoting novel product innovation, suppliers rank higher than customers for firms with only a single type of collaboration. Deeper relationships are important in this regard. In their analysis of 182 industrial firms in the Netherlands, Berghman, Matthyssens, and Vandenbempt (2012) show that increasing levels of information obtained through day-to-day collaboration with suppliers helps firms to translate inbound knowledge flows into novel innovation. Thus, we posit that:

H1. Supplier embeddedness and product or service innovation are positively related, taking a convex (increasingly upward sloping) shape indicative of the increasing benefits of deep embeddedness.

2.3. Deep customer embeddedness

Customers are important for new product or service innovations because of the tight link between innovation and managing inter-organisational projects that typify integrated solutions industries. For instance, the innovation activities of UK construction firms and engineering services firms are heavily influenced by clients' shifting requirements (Acha et al., 2005; Barrett & Sexton, 2006). Similarly, in the oil and gas industry, developing and commercialising products is tightly linked to exploration projects (e.g., searching for, and validating, oil and gas deposits), as well as customers' capital development projects (i.e., building the infrastructure to produce and sell the oil and gas) (Bower, Crabtree, & Keogh, 1997; Daneshy & Donnelly, 2004). That is to say, oil and gas firms introduce new products by testing them directly on customers' projects, an outcome that can only be achieved when customers encourage such testing using their own assets (for instance, on their oil wells) (Bower et al., 1997).

The literature agrees that deep customer embeddedness is vital to innovation. For example, in a review of the UK construction industry, Reichstein et al. (2008) indicate that firms with high levels of customer input are six times more likely to introduce product innovations when compared with firms using low levels of customer input. These authors speculate that this is due to significant involvement of clients who articulate their vision and drive technology decisions in the early design and production stages of projects (Reichstein et al., 2008). Similarly, as a result of studying product innovations in Australian construction firms, Manley (2008) observes that product innovation is improved when firms work closely with clients who have high technical steering competency. Again, deeper relationships are especially important, as illustrated in the case of UK manufacturing firms, where frequent interactions with lead users and customers were shown to be strongly related to new-to-the-world products (Laursen & Salter, 2006). We therefore posit that:

H2. Customer embeddedness and product or service innovation are positively related, taking a convex relationship shape indicative of the increasing benefits to of deep embeddedness.

2.4. Embeddedness trade-offs

While we have argued that deep customer and supplier embeddedness supports product or service innovations, this section suggests that simultaneous vertical embeddedness with both customers and suppliers can be detrimental to the introduction of new products or services. In the *Limits of attention* section, we draw upon the attention-based view of the firm to describe the potential limits of having multiple network partners when innovating, particularly in project-based settings. In the *Lock-in* section, we look at how this theory might explain how being a broker between suppliers and customers may put pressure on firms to be non-innovative. In the *Vertical embeddedness* section, we integrate these perspectives to hypothesise that maintaining both types of relationships may detract from innovation.

2.4.1. Limits of attention

The attention-based view of the firm posits organisational performance depends on how firms allocate attention to the various problems they face (Ocasio, 1997). In particular, there is much interest in how firms allocate their limited attention resources to look for, and execute, the next major innovation (Koput, 1997; Laursen & Salter, 2006; Li et al., 2013). This theory posits that attention is limited and thus allocating it in the wrong ways can lead to suboptimal performance. For instance, Koput (1997) argues that (a) paying attention to too many ideas, (b) focusing in the wrong areas and at the wrong times or (c) not applying adequate attention to the problems at hand, can all lead to a reduction in innovation performance.

As attention span relates to collaborations, maintaining too many innovation relationships can lead to suboptimal innovation performance. This point is illustrated by a global survey of mostly manufacturing firms that found that using a more parsimonious and selective sourcing strategy for supply chain partnerships was more likely to derive innovation benefits than broad inclusiveness (Luzzini et al., 2015). For UK manufacturing firms, Laursen and Salter (2006) reveal that there are decreasing returns to innovation when firms maintain too many different types of collaborative relationships. Their study shows that collaboration depth operationalised the total number of different groups with which a firm collaborated, and took a curvilinear (Inverted-U) shape relative to innovation performance. Firms that extensively collaborated with many different groups (including a range of partners like suppliers, customers, competitors, consultants, commercial labs, universities, and government research institutes) achieved sub-optimal innovation performance compared to firms that focused on fewer collaborators.

This evidence suggests that it is challenging for firms to use the information coming from many collaborators. Having too many deeply embedded relationships may overwhelm limited attention resources and, because the organisation cannot fully attend to all of these potential loci of innovation, the innovation potential of the firm is reduced.

Regarding this paper's research setting, the limits of attention may manifest quickly because of the nature of project-based organizing. In construction settings, and oil and gas specifically, projects are both the organizing principle for all work and the backdrop for innovation (Acha et al., 2005; Crabtree et al., 1997; Gann & Salter, 2000). This means that attention is not simply allocated to integrating the knowledge from suppliers and customers in order to innovate. Attention is divided between this and the primary activity: the execution of inter-organisational projects that support the firm's livelihood. Thus, attention is already stretched thin as the firm attempts to reconcile many project-based knowledge gaps, such as those caused by the separation of project teams from the parent organisation, or attempts to transfer learnings from past projects to the current one (Brady & Davies, 2004; Davies & Brady, 2000; Gann & Salter, 2000; Prencipe & Tell, 2001). Attention left over for innovation purposes may be limited.

Thus, vertically embedded firms in this setting effectively have a three-way attention problem: suppliers, customers *and projects*. Faced with these competing priorities, the project takes the majority of attention since current project performance helps to ensure that the firm gets a chance to participate in the next one. This means that attention is drawn away from vertical relationships with customers and suppliers which, in turn, decreases their potential value toward innovation.

2.4.2. Lock-in

Manning and Sydow (2011) argue that collaborative relationships between firms are path-dependent: shaped by a combination of historical choices and chance occurrences, each reinforced by positive feedback (Arthur, 1989, 1990). In our study, lock-in refers to the scenario in which firms are vertically embedded with both suppliers and customers because of strong historical ties.

Collaboration lock-in may limit innovation because feedback reinforces existing relational structures that are built upon simultaneously satisfying customer and supplier needs. The pitfalls associated with this are numerous and are caused by ossified relational structures that limit the amount of change a focal firm can introduce. Locked-in firms are limited in their ability to create new products or services because they are pre-occupied with meeting the current and often pressing demands of multiple partners (Whitley, 2002). Ongoing obligations serve to limit managerial discretion to try new combinations, which directly undermines innovation potential (Schreyogg & Sydow, 2011). Furthermore, the positive feedback around the delivery of reliable technologies means that firms face resistance from network partners in any effort to drastically alter the technologies or services to which the vertical network has grown accustomed (Whitley, 2002).

That vertical lock-in may impair innovation performance is supported in much research. For example, in computing markets, prior successes have been shown to reinforce existing network connections rather than support the building of new relationships. This in turn limits strategic thinking and undermines the reaction to shifts in competition so that firms are not able to adequately distinguish new entrant threats (Håkansson & Ford, 2002). In complex product industries, departing from a stable role as a technological provider may actually jeopardise a firm's reputation as a low-risk partner in the network, and may undermine the potential for them to be selected by the same partners in the future (Whitley, 2002). In such settings, vertical obligations mean that firms must reconcile the competing priorities of network partners by keeping them placated about their technological needs. Rather than resulting in innovation, the focal firm is likely to end up brokering the most straight-forward technological or service solution, one that is undoubtedly already on the market, has been well-tested, and has a track record.

Repeated interaction with the same partners also serves to reduce innovation potential. As Skilton and Dooley (2010) argue, repeating the same collaboration patterns promotes shared mental models which, in turn, stifles the creativity necessary to produce novel outcomes. This is because 'creative abrasion' is suppressed by repeated collaborations because project members are less likely to break away from established mental and structural models that have been created as a result of repetition. Furthermore, Uzzi (1997) argues that multiple ties with similar types of firms may reduce the flow of new information to the focal firm. If a firm lacks new information because it serves a stable position of brokering between customers and suppliers, innovation will be constrained by the limited information flows from this stable structure. The vertically embedded firm therefore is not privy to the unique information necessary to derive new innovations (Cohen & Levinthal, 1990; Dahlander & Gann, 2010). This, in turn, would result in only incremental changes that are closely related to current products (Atuahene-Gima, 2005; Knudsen, 2007; Leonard-Barton, 1992; Levinthal & March, 1993; March, 1991).

Therefore, we anticipate that vertical embeddedness will negatively relate to product or service innovation in our research setting, simply because the firm that is beholden to the desires of multiple network partners and repeated interactions that serve to placate all of them means that old products or services, not new products or services, will prevail.

2.4.3. Vertical embeddedness

We argue that attention and lock-in theories work in tandem to explain how increasing levels of vertical embeddedness reduces innovation in our research setting. Linking these two theories is the strong role of the customer that directly impacts innovation propensity.

Customer-led projects draw focal firms' attention away from innovative suppliers. As it relates to the attention-based view, some project-based industries like those in the oil and gas sector have relatively few major customers and large diversified supply chains of specialist providers. In these settings, customers are effectively system integrators that coordinate large supply chains of specialists to produce low-volume, specialised, complex products (Davies et al., 2007; Hobday et al., 2000). When a firm (with limited attention) is working in such an environment and it is faced with attending to their suppliers, or to the customer and the current project they sponsor, it seems likely that supplier attention would be reduced. This would serve to limit innovation potential by taking away a useful source of information, and would result in the focal firm delivering already existing products or services.

As it pertains to lock-in, customers are risk-averse toward innovation. Customers delivering high-cost infrastructure and products have a proclivity for well-tested technologies, especially those in construction and oil and gas (Daneshy & Donnelly, 2004). These industries have very high safety standards, which may reduce the appetite for risk that novel innovations represent. This, in turn, puts pressure on existing technology and at most firms make very incremental improvements to it. There are financial risks as well. To the project owners who are responsible for delivering upon the sizable capital investments made by their investors, innovation is not often viewed as a strength but as a potential liability that should be minimised (Keegan & Turner, 2002). Hence, low-risk technological choices are used to deliver the project because they provide certainty of outcome. Any potential advantage that could be derived from innovation is too risky to explore when making such significant capital investments. This means that focal firms in our setting are likely to receive positive feedback for being incremental, not innovative. This feedback becomes reinforcing because delivering certain outcomes (again, through non-innovative products or services) becomes the selection criteria used by the customer to select the focal firm in future projects. This means that a cycle of non-innovative behaviour ensues.

Therefore, in our research, both attention and lock-in theories combine to explain how innovation potential is reduced when firms are vertically embedded. We argue that a focal firm's attention will be drawn to customers and their projects (and away from innovative suppliers). While holding their attention customers will exhibit a risk-averse preference for non-innovative products or services, behaviour that is rewarded over time and becomes locked in (Fig. 1). Thus, we hypothesise that:

H3. Customer embeddedness negatively moderates the relationship between supplier embeddedness and product or service innovation.

3. Methods

3.1. Survey

The data used in the analysis were obtained using a survey instrument that follows the OECD's *Oslo Manual Guidelines for Collecting and Interpreting Innovation Data* (2005). Oslo-type surveys support firm-level analyses (Tether & Tajar, 2008) by directly assessing the introduction of innovations and their performance, finances, competitive attributes, and collaboration activities of firms (Cosh & Hughes, 2009; Tether & Tajar, 2008). The specific survey used in this research originates from Cambridge University and its Centre for Business Research (CBR), and has been well tested in the UK and Australia (Cosh, Fu, & Hughes, 2012; Cosh & Hughes, 2000, 2003, 2007; McCarthy, Oliver, & Verreynne, 2015).

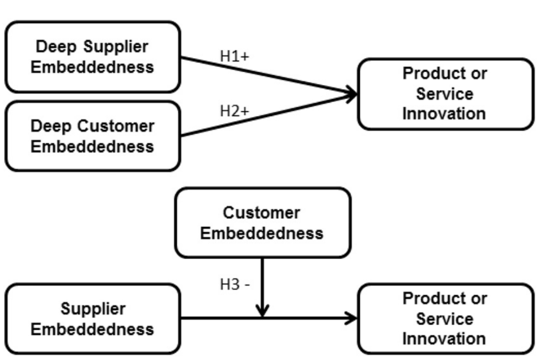

Fig. 1. Research model and hypotheses.

Table 1
Sample and response rate.

	Sample		Frame		Overall response rate
	N	split	N	split	
Operators	58	34%	182	28%	32%
Service firms	115	66%	464	72%	25%
Totals	173	100%	646	100%	27%

3.2. Sample

The firm-level data used in this study stem from two survey waves conducted in late 2012 and again in late 2013 – early 2014. Both waves used the same survey questions. Most responses were obtained from different firms each time, with only slight overlap in responding firms (which we account for statistically in the next section, *Regression models*). In our efforts we phoned executives and owners of the businesses in membership ranks of the Australian Petroleum Production and Exploration Association (APPEA). This group represents 98% of Australian oil and gas production capacity (APPEA, 2012). The second period, sample was also drawn from the membership of the Toowoomba Surat Basin Enterprise (TSBE). The combined sample and sample frame is shown in Table 1. We obtained an overall response rate of 27%, which is in line with surveys of executive-level leadership (Baruch, 1999).

3.3. Regression models

We conducted the analysis in STATA (version 14) using logistic regressions that were simultaneously estimated. We specified clustered standard errors in our estimation to account for the intra-class correlation between repeat firms (35 in total) so that the standard errors of their estimates would be not be underestimated, thereby making the significance calculations very conservative. We utilise the appropriate statistical methodology to account for repeated measures. That is, the cluster sandwich estimator (vce (cluster *clustvar*) command in STATA), as used by us, is the correct approach to account for the lack of independence between the repeated measures of the same firm, and has been used for this purpose in similar research (Beckman & Burton, 2008; Fahlenbrach, 2008; Villalonga & Amit, 2006; Zhi, Hai, & En, 2016). Furthermore, all significance levels reports are 2-tailed; no 1-tailed tests were applied. For these reasons, we consider our models to be very conservative with regards to significance of regression coefficients.

3.4. Latent class analysis

To explore potential heterogeneity in our sample and the implications of this on interpreting our findings we conducted a latent class analysis (LCA) (Forkmann et al., 2016). Specifically, we used LCA to categorise firms by embeddedness with suppliers and customers, using the 18 binary collaboration mode indicator variables (i.e., nine modes each for suppliers and customers; refer to the Appendix A and B) and employing the maximum likelihood robust (MLR) estimator available in *Mplus* software. LCA is a technique used to identify unobserved heterogeneity in a population, assigning individuals to empirically derived classes, with the optimal number of classes determined by a combination of the Bayesian information criterion (BIC), the Bayesian information criterion sample size adjusted (BIC-SSA) and the Lo-Mendell-Rubin adjusted likelihood ratio test (A-LMRT) (Nylund, Asparouhov, & Muthén, 2007). After determining the 'best' fitting model (ranging from two to five classes), the firms' class probabilities were then exported to *Stata* for regression analysis in which the class variable was used to define sub-groups for which the main analyses were to be re-run separately. Importantly, when the 'best' fitting model's entropy is high (usually defined at > 0.8) it is acceptable to assign individuals to their most likely class for further regression analyses (our models had very high entropy at ≥ 0.95 – see results) (Clark & Muthé, 2010). The regression analyses were then re-run separately using the LCA defined subgroups in Stata.

3.5. Variables and measures

This section introduces the variables and measures used in the models. Details of the variables, including question stems and response anchors, are included in the Appendix B: *Variables*.

3.5.1. Dependent variables

3.5.1.1. Product or service innovation. This is a dichotomous variable that indicates the introduction of a product or service innovation within the last three years that is either new to the firm or new to the industry.

3.5.1.2. Innovator. This dichotomous variable indicates the introduction of any of six innovation types of innovation (i.e., product, process, logistic, service, service delivery and marketing or management).

3.5.1.3. Product innovation. This dichotomous variable indicates the introduction of a 'technologically new or significantly improved physical product or technology'.

3.5.2. Independent variables

3.5.2.1. Supplier and customer embeddedness. We follow the economic geography literature in which collaborations are used to measure embeddedness (Collinson & Wang, 2012; Love, Roper, & Hewitt-Dundas, 2010; Song, Asakawa, & Chu, 2011). For instance, Love et al. (2010) analyse the relationship between local and international embeddedness and innovation within Irish firms. They define embeddedness as the presence of local, and also non-local, collaborations with suppliers, customers, competitors, universities, and labs or consultants. Similarly, Song et al. (2011) describe embeddedness as the number of relational ties that international R&D offices have with local entities such as universities and research institutions. Collinson and Wang (2012) say that the number of external entities used for innovation purposes is a proxy measure of embeddedness. Thus, we follow this approach and operationalise embeddedness as the number of collaborative ties held with suppliers and customers.

Embeddedness was calculated by summing the use of nine possible collaboration modes with either suppliers or customers. The Cronbach alpha for *supplier embeddedness* is 0.722 and, for *customer embeddedness* (denoted CUST), 0.762 showing relatively high levels of internal consistency (cf. Field, 2009; Hair, Anderson, Tatham, & Black, 2010).

3.5.2.2. Deep supplier and customer embeddedness. We argue that deep embeddedness represents an exponential combinatory capability that stems from having a number of collaborative relationships that can be drawn upon to address contingent innovation problems. Therefore, we used the squared terms of customer and supplier embeddedness to operationalise deep embeddedness. This approach is similar to Wu (2014) and Laursen and Salter (2006), who use quadratic terms to test for excessive cooperation. Their purpose was to understand the shape of the regression curve, and the point at which cooperation became too much for firms to manage and thus began to detract from performance. However, we argue that deep embeddedness increases performance. It increases the combinations of collaborators that can be created. As firms become practised at managing these combinations, this positively affects their collaborative capabilities, which accelerates innovation. These capabilities essentially unlock the combinatory potential of collaborations. Therefore, we view this relationship positively, terming it 'deep', rather than 'excessive' embeddedness.

The operationalisation of deep embeddedness with a squared term therefore signifies that firms are capable of maintaining a much deeper set of collaborative relationships with suppliers and customers, rather than a linear relationship.

3.5.2.3. Vertical embeddedness. This variable is the interaction term between supplier and customer embeddedness.

3.5.3. Control variables

3.5.3.1. Research and development (R&D). A control for research and development (R&D) is used for to represent innovation capabilities (Cohen & Levinthal, 1990). We include the presence of R&D activities as this indicates an ongoing commitment to developing important skills required to capture and use external knowledge in the innovation process (Moilanen, Østbye, & Woll, 2014).

3.5.3.2. Size. This is a control for firm size based on the number of full-time staff and contractors employed by the firm; it is log transformed to correct for positive skew.

3.5.4. LCA support variables

After identifying separate sub-groups using LCA, a number of indicators of external engagement were employed to probe for differences between the sub-groups.

3.5.4.1. Search breadth. Search breadth is the sum of 12 possible information sources used for innovation purposes (Laursen & Salter, 2006).

3.5.4.2. Search depth. Search depth is the sum of 12 heavily used information sources used for innovation purposes (Laursen & Salter, 2006).

3.5.4.3. Total collaborations. This variable is the sum of total number of collaborations across five different types of collaborators.

3.5.4.4. Service firm. This is a binary variable indicating if the firm is an oil and gas operator or a firm within the supply chain of the sector (0 = operator, 1 = service).

3.6. Bias testing

To test for selection bias, a chi-square test of the difference between the sample frame and the sample obtained was found to be insignificant at the $p < 0.05$ level ($\chi^2 = 1.786$, $df = 1$, *n.s.*). Because of this finding, coupled with the survey respondents being part of the premier industry trade group's membership, which represents 98% of the firms in the industry (APPEA, 2012), we consider selection bias not to be a problem.

To test for non-response bias, firms were split into early and late responder groups as delineated by the halfway mark of each of the collection campaigns (cf. de Villiers & van Staden, 2010). This is because late responders should reflect non-responders (Armstrong & Overton, 1977). We found that there were no significant differences between the two groups.

Common method bias (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003) was assessed by subjecting all variables to the Harman single factor test (Leiponen & Helfat, 2010; Podsakoff & Organ, 1986). There are two reasons why we found no cause for concern. First, we consistently found two factors, of which the first accounted for no > 40% of the variance. Second, the parsimonious nature of the models means the test is very conservative (Podsakoff & Organ, 1986) and nevertheless, two distinct factors still emerged.

Table 2
Spearman's Rho correlation table.

		M	S.D.	1	2	3	4	5	6
1	INNOVATOR	0.70	0.46						
2	PRODSERV	0.56	0.50	0.741**					
3	SUPP	0.85	1.53	0.309**	0.325**				
4	CUST	0.56	1.29	0.271**	0.274**	0.561**			
5	SUPPCUST	1.84	6.71	0.232**	0.232**	0.700**	0.874**		
6	RD	0.54	0.50	0.176*	0.277**	0.182*	0.177*	0.160*	
7	LOGSIZE	1.78	0.92	0.203**	0.138	0.223**	0.249**	0.231**	0.140

$^{+}p < 0.10$.
$^{*}p < 0.05$.
$^{**}p < 0.01$, two-tailed.

4. Analysis and findings

The Spearman's Rho (non-parametric) correlation is shown in Table 2. Product or service innovation positively correlates strongly with supplier embeddedness and moderately with customer embeddedness. The interaction term for vertical embeddedness is positive and significant with new product or services introductions. There is no relationship with size. The research and development control is positive with the main dependent variable.

Table 3 shows the results of the main models for product and service innovation. The full models, which specify embeddedness, deep embeddedness, and the interaction term for vertical embeddedness, provide support for all three hypotheses. In Model 2 (without controls) and Model 3 (with controls), deep supplier embeddedness and deep customer embeddedness significantly and positively relate to product or service innovation, thus supporting both H1 and H2. The interaction term across both of these Models (2 and 3) is negative and significant, supporting H3.

To explore the effect of deep embeddedness on product or service innovation, we plotted the log odds of deep customer and deep supplier embeddedness across the range of values that each could take, keeping the other variables at their means (see Fig. 2). This plot clearly shows an increasing return to embeddedness in each collaborative mode. At the limit, it appears that deep customer embeddedness begins to payoff more substantially than deep supplier embeddedness.

To further explore the vertical embeddedness interaction term, we developed a plot shown in Fig. 3. The graph plots embeddedness from zero to two standard deviations above the mean. This exercise reveals that, at high levels of supplier embeddedness and low levels of customer embeddedness, there is a high probability of novel product innovation (left hand side of the dotted curve). However, as customer embeddedness increases, firms become far less likely to develop new products or services (shown to the far right of the dotted curve). The cross-over between the two lines indicates a trade-off effect.

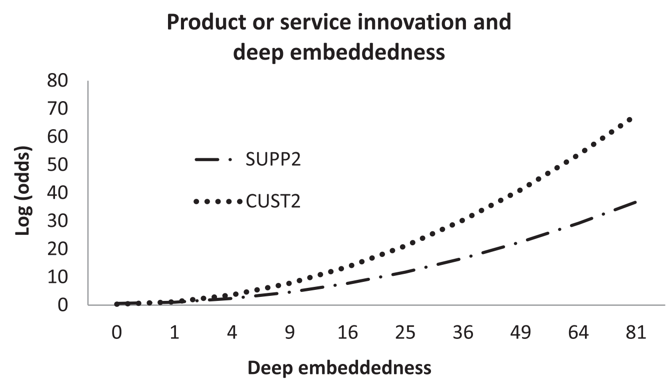

Fig. 2. Deep embeddedness.

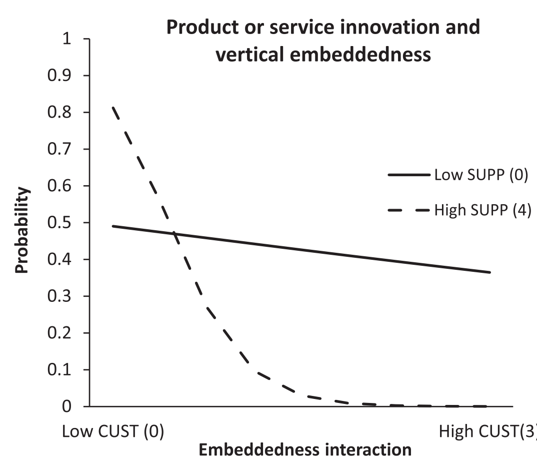

Fig. 3. Trade-off interaction between supplier and customer embeddedness.

Table 3
Main models of embeddedness trade-offs.

	Main models	
	PRODSERV	
	(1)	(2)
SUPP	− 0.324+	− 0.285
SUPP2	0.467*	0.447*
CUST	0.004	− 0.200
CUST2	0.758*	0.833*
SUPPCUST	− 0.895**	− 0.905**
LOGSIZE		0.103
RD		0.988**
Constant	− 0.243	− 0.900*
N	173	173
pseudo R^2	0.138	0.177
ll	− 102.210	− 97.689
AIC	216.420	211.379
BIC	235.340	236.605

Simultaneously estimated logistic regressions with clustered standard errors.
$^{+}p < 0.10$.
$^{*}p < 0.05$.
$^{**}p < 0.01$, two-tailed.

4.1. Robustness testing

We conducted additional tests to see if the findings of the main models were robust. First, we analysed other dependent variables that were innovation-related. This test produced a repeating pattern of positive relationships to innovation stemming from customer and supplier embeddedness, and a negative interaction between them. Second, we conducted the latent class analysis that was described in the *Methods* section.

Table 4
Alternative dependent variable robustness tests.

	INNPROD	INNOVATOR
	(3)	(4)
SUPP	− 0.050	− 0.249
SUPP2	0.361 +	0.613 +
CUST	0.098	0.267
CUST2	0.416 +	1.318*
SUPPCUST	− 0.707*	− 1.633*
LOGSIZE	0.094	0.278
RD	0.561**	0.266
Constant	− 0.521*	0.415 +
N	173	173
pseudo R^2	0.172	0.166
AIC	214.544	192.496
BIC	239.771	217.722
ll	− 99.272	− 88.248

Simultaneously estimated logistic regressions with clustered standard errors.
+ $p < 0.10$.
* $p < 0.05$.
** $p < 0.01$, two-tailed.

4.1.1. Alternative dependent variables and model specifications

In the first analysis, we found that product innovation (Model 3) and innovation of any type (Model 4) directly mirrored the results of the original model. In both models, we found that deep customer and deep supplier embeddedness positively predict these two alternative dependent variables, and the interaction term is also significant and negative (see Table 4).

In the case of innovation (any type, Model 4), the negative interaction term is very large. This interaction curve is plotted in Fig. 4.

To ensure that our combined sample (that included 35 firms that responded in both waves of our survey) was providing robust results, we interrogated the data in several additional ways. We compared the means (or proportions for binary comparisons) across all variables for the 35 repeat measures obtained in each of the two survey waves, 2012 and 2013, and found no concerning differences. We also compared the means (or proportions) between data collected in each year excluding the repeat firms. That is, we removed the 35 firms from 2012 sample and compared those means with the full 2013 sample, and removed 35 firms from the 2013 sample and compared it to 2012. In both cases we found no measures with statistically significant differences. Further, we replicated the logistic regressions for all of our dependent variables using data from both years but excluded the 35 firms, firstly from 2012 and subsequently from 2013, and the results did not change substantively. Importantly, the main effects, for deep supplier and customer embeddedness and negative interaction between customer and supplier embeddedness, remain significant in our main model

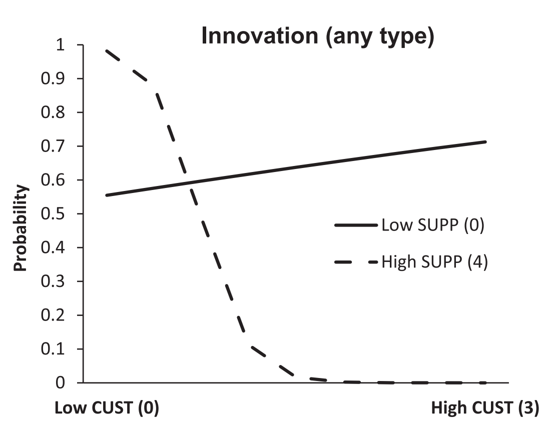

Fig. 4. Trade-off interaction for innovation (any type).

Table 5
Comparison of fit indices for latent class analysis of the 18 collaboration modes.

Class number	Fit indices			
	BIC	BIC-SSA	Entropy	A-LMRT
2 class	1466	1349	0.95	< 0.001
3 class	1474	1296	0.96	0.177
4 class	1529	1291	0.96	0.586
5 class	1595	1298	0.96	0.745

regardless of these alternative specifications. Therefore we consider the results to be very robust, and the use of the full sample and robust standard errors in our model specification to be most appropriate (see the Appendix A: *Alternative model specifications*).

4.1.2. Latent class analysis

The LCA, the BIC and A-LMRT results clearly indicate that the 2-class LCA is the 'best' representation of the data (see Table 5) and that all models have high entropy (indicating the firms are allocated to the classes with little uncertainty). The A-LMRT indicates if the k solution provides a significantly better fit compared with the k-1 solution, which in our analyses holds only for the 2-class solution. Furthermore, the 3-, 4- and 5-class solutions produced classes with very small memberships (one class in the 3-class solution included only 7 firms). Such classes indicate over-extraction and are thus inadequate for further regression analyses.

Fig. 5 shows the probability of item endorsement for the 18 collaboration modes for the two classes. The chart shows nine individual collaboration modes for suppliers, denoted S1 through S9, and nine modes for customers, denoted C1 through C9 (see Appendix B: *Variables* for all corresponding codes). This model indicates that firms fall into one of two groups, with the majority (74.3%) having a low probability of collaboration across any mode (labelled the non-collaborative group), and the second group comprised of a minority of firms (25.7%), which have a low to moderate probability of engaging in all collaboration modes (labelled the collaborative group). The collaborative group has the highest probability of engaging with suppliers to gain access to new equipment, technology or information (S2), streamlining the supply chain (S4), and is likely to engage with both suppliers (S7)

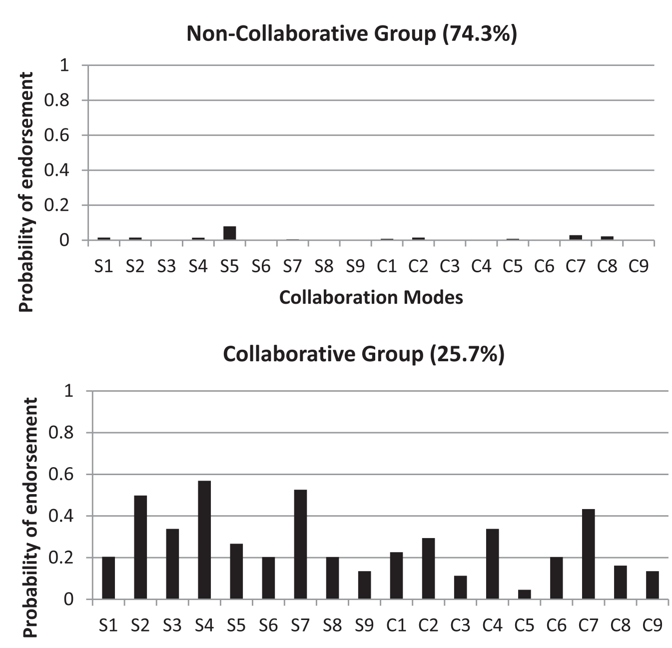

Fig. 5. Probability of collaboration mode endorsement for the two classes.

and customers in development of specialist services or products required by customers.

Logistic regression was then used to determine if classes differed by indicators of external engagement and service sector; we found significant associations between being in the collaborative group with the number of total collaborations (OR = 1.64: 95% CI = 1.41, 1.92) and search breadth (OR = 1.19: 95% CI = 1.08, 1.30), but non-significant association with service firms (OR = 1.93: 95% CI = 0.87, 4.27) and search depth (OR = 1.14: 95% CI = 0.94, 1.37). This indeed indicates that the collaborative group appears to be more externally focused, both in the depth of collaborations with other groups, as well as in searching for innovation-related information.

Prior to re-running the regressions from the main analyses separately on the two subgroups, we noted that the number of collaboration modes endorsed in the non-collaborative group was insufficient to make a count variable (supplier modes: n = 12 endorsed one mode, n = 3 endorsed two modes; customer modes: n = 9 endorsed one mode, n = 1 endorsed two modes), and were insufficient to create a quadratic term or interaction. Thus, we created binary variables of any customer innovation (yes/no) and any supplier innovation (yes/no) to use in the regression analyses for this sub-group. The results replicating the main analyses (refer to Table 3) are presented in Table 6. For the collaborative group, we lose significance for deep supplier embeddedness (H1), although its sign remains the same and the effect size similar to the original model. The results for deep customer embeddedness (H2) remain positive and significant, and vertical embeddedness (H3) is still statistically significant and negative, replicating the finding from the analyses of the full sample (H3). However, among the non-collaborative group it was not possible to test an interaction, and endorsing one or two supplier or customer modes was not significantly associated with the outcome.

Next, we re-ran the logistic regression models using the alternative dependent variables (refer to Table 4), product innovation and innovation of any type, shown in Table 7. It was not possible to reproduce the regression model using innovation of any type as the dependent variable in the collaborative group because the small numbers led to a number of covariate patterns that perfectly predicted the outcome. The results for product innovation replicate those in Table 6. For the collaborative group we lose significance for deep customer embeddedness. Support for deep customer embeddedness remains (H2), as is the negative interaction representing vertical embeddedness (H3). Meanwhile in the non-collaborative group the main effects of the binary embeddedness variables significantly predicted product innovation, but not innovation of any type.

Table 6
Main models of embeddedness trade-offs – separate by latent classes.

	Collaborative group			Non-collaborative group	
	Product or Service Innovation			Product or Service Innovation	
	(1)	(2)		(1)	(2)
SUPP	0.946	1.447	SUPP_BIN	0.926	0.754
SUPP2	0.433	0.317			
CUST	− 0.204	− 0.256	CUST_BIN	1.624^{+}	1.462^{+}
CUST2	1.269^{+}	1.290*			
SUPPCUST	− 1.243*	− 1.275*			
LOGSIZE		− 0.164	LOGSIZE		0.116
RD		1.039	RD		0.893*
Constant	− 3.272	− 3.808	Constant		− 0.920^{+}
N	43	43	*N*	130	130
pseudo R^2	0.345**	0.370	pseudo R^2	0.041	0.077
ll	− 13.53	− 13.01	ll	− 86.259	− 83.07
AIC	39.07	42.01	*AIC*	178.518	176.14
BIC	49.63	56.10	*BIC*	187.121	190.47

Simultaneously estimated logistic regressions with clustered standard errors.
$^{+}$ p < 0.10.
* p < 0.05.
** p < 0.01, two-tailed.

Table 7
Alternative dependent variable robustness tests – separate by latent classes.

	Collaborative group			Non-collaborative group	
	INNPROD	INNOVATOR		INNPROD	INNOVATOR
SUPP	0.702	–	SUPP_BIN	1.100^{+}	0.851
SUPP2	0.210	–			
CUST	0.207	–	CUST_BIN	1.82*	1.665
CUST2	0.472^{+}	–			
SUPPCUST	− 0.769*	–			
LOGSIZE	− 0.260	–	LOGSIZE	0.154	0.261
RD	0.541	–	RD	1.133*	0.449
Constant	− 2.040	–	Constant	− 1.491*	− 0.312
N	43	–	*N*	130	130
pseudo R^2	0.252**	–	pseudo R^2	0.122	0.057
ll	− 19.04	–	ll	− 77.16	− 81.24
AIC	54.078	–	*AIC*	164.32	172.49
BIC	68.167	–	*BIC*	178.66	186.82

Simultaneously estimated logistic regressions with clustered standard errors.
$^{+}$ $p < 0.10$.
* $p < 0.05$.
** $p < 0.01$, two-tailed.

5. Discussion

Our empirical study expands how we view the role of vertical relationships in supporting product or service innovation to show the trade-offs that firms in integrated industries may face. In the overall sample, we find strong empirical evidence that deep supplier and customer embeddedness positively relate to product or service innovations, but we also find a negative interaction between the two. This suggests that having deep collaborations with either supplier or customer groups can be beneficial, but trying to manage both may be problematic. The negative interaction suggests that there is a substitution effect. This implies firms may be lacking in attention switching capability. An alternative interpretation is that firms lacking this switching capability are more prone to become vertically embedded and thus non-innovative. That is, their innovative potential is supressed because they are locked into the delivery of repeat products or services that very closely mirror existing offerings.

Our sample exhibited heterogeneity with regards to collaborative mode profiles, with LCA demonstrating that firms belonged to one of two groups, one in which collaboration was moderate on average and the other in which collaboration was low or non-existent. Importantly, among the collaborative group, the negative interaction found in the full-sample analysis was replicated, and in the non-collaborative group, in which inclusion of an interaction was prohibited owing to lack of collaboration, any customer or supplier collaboration predicted the outcomes. The next sections of this study focus on these findings and elaborate on the theoretical implications and contributions of each.

5.1. Theoretical contributions

We claim two major contributions. First is our finding of a positive, increasingly upward sloping relationship between firms that focus on particular collaborator groups, either with suppliers or customers, and innovation. Our results show that, as firms become more deeply embedded with either group, there are increasing returns to introducing new products or services. Whereas others have found a decreasing return related to being overextended (broadly spread) across many collaborator groups (Laursen & Salter, 2006), we find with increasing depth within one type of collaborator yields an exponentially increasing relationship with innovation. Depth provides firms with information heterogeneity. This heterogeneity comes from the great number of partner combinations that can be formed to address innovation problems. This, coupled with the ability to call upon and use these partnerships adeptly, contributes to higher probability of innovation outcomes.

Our second contribution regards attention switching capabilities. Evidence of attention switching for the firms in our sample would have manifested as a positive interaction between customer and supplier embeddedness in our models. This would have indicated a reinforcing effect between being embedded with both customers and suppliers groups and that firms have managed to leverage information advantages of both. Firms with attention switching capabilities would overcome the information overload that the attention based theory of the firm predicts would lead to poor performance (Laursen & Salter, 2006; Ocasio, 1997). These capabilities would enable firms to make the most of these deep connections they have by allocating attention to each group when needed (depending on the circumstances), and preserving the innovation potential of each. Within the innovation literature, such a switching capability has long been important in explaining how firms change from 'business as usual' to creating new products that depart from the norm (March, 1991; O'Reilly & Tushman, 2004).

Instead we found negative interaction between supplier and customer embeddedness and product or service innovation. Our plots suggest that firms may have a better chance of innovating with either high levels of customer embeddedness (and low supplier), or high levels of supplier embeddedness (and low customer). Thus, the findings somewhat indicate the informational processing limitations of the firm (Bonner, 2010; Laursen & Salter, 2006; Ocasio, 1997) and a lack of attention switching capability.

Furthermore, the lack of attention switching capability may also indicate the ill-effects of being vertically embedded: firms become locked into playing non-innovative network roles by placating both customers and suppliers. Firms may become so bound to their suppliers and customers that they lose the capability to manoeuvre against the stable technological trajectory into which their immediate network has evolved. In such cases, firms will deliver the ordinary products or services to placate their stable network partners. Additionally, routine engagement with them reduces managerial choice and limits the availability of new information. This means that firms will find it difficult to develop innovations that depart far from the current offerings. These conditions tend to promote only incremental improvements to existing products and services.

The vertical embeddedness findings also suggest that the strong role of the customer may adversely influence innovation potential. Customers who sponsor, or play major roles in, industry projects will draw focal firms' attention away from more innovative suppliers. Indeed, the plots in Figs. 3 and 4 clearly show that innovation is more likely when firms are deeply embedded with suppliers and not customers, rather than the other way around. The results of the LCA further reinforce this. For the collaborative group in the LCA model (refer to Table 6), the significance of product or service innovation for supplier embeddedness vanishes and the negative effect size for the interaction effect diminishes (from − 0.91 to − 1.28), as compared with the main model (refer to Table 3). It seems that even highly collaborative firms lack the capability to make the most of customer and supplier embeddedness, succumbing to the influence of customers and not leveraging their suppliers for innovation. Those that attempt to remain embedded at both ends may end up simply brokering existing solutions and being rewarded for this incremental behaviour since it solidifies their reputation as a reliable network partner and increases the chances to be chosen for future projects.

5.2. Managerial implications

Managerial attention is limited and must be focused on the most important matters at hand. These may include ongoing industry projects and new product or service projects being undertaken for important customers. For instance, focusing attention on important clients and delivering successful outcomes on time and on budget improves the chances of securing future work. However, there are potential disadvantages to this intense focus that may limit the ability to develop new, high-value product or service solutions to the market. While a firm's suppliers potentially provide new product or service ideas, a firm may risk missing these supplier-side innovation opportunities in the midst of delivering on its existing obligations to customers.

An important finding from our research is that, if a firm can balance the attention it pays to customer needs and supplier potential, it may still be able to deliver important new products or services to market. However, because not every good supplier idea can make it into what is offered to customers, the key may lie in a portfolio approach that allows ideas to be maintained as options until an opportune moment arises to execute them, such as a rare visionary project led by a particularly innovative customer. A portfolio of investments in several innovation options can be separated from the day-to-day running of the business, for instance, by investing in R&D projects that are not tied directly to ongoing projects with customers. This buffers innovation activities from typical risk-averse customer requirements that might suppress novelty. Furthermore, adopting a strategic approach to this portfolio will help to direct the firm's limited R&D resources toward the highest value innovation targets, thus preventing attention being spread across too many options with lower probabilities of improving business outcomes.

The real risk in not cultivating the ability to shift attention between innovation and delivering tried-and-true products or services is that customers will come to prize certainty over newness. In the short term, not innovating will be the surest way to maintain reputation as a reliable partner. In the long term, however, it puts a firm at substantial risk that another provider will innovate and change the face of the industry, leaving the focal firm to play catch-up.

5.3. Limitations and future research

This study has some limitations. For instance, given that it focuses on Australian oil and gas firms, generalising the study should be undertaken with caution. However, we posit that other large industries (such as construction) would exhibit similar patterns. It may be that, in other industries where collaborative endeavours are not focused on delivering complex product systems and associated services, the propensity for attention deficit and lock-in are not as prevalent or present at all. Therefore, we suggest further replication studies should be undertaken, based on our simple proxy measure of structural embeddedness.

Additional analysis of interaction effects between different types of network partners seem one plausible method of quickly improving our understanding of networking capabilities. Accessing national data sets (such as the UK's Community Innovation Surveys), which have similar collaboration questions as our survey, would afford scholars the statistical power to investigate other network trade-offs including: firms in the same line of business, research institutes, consultants, and other types of network partnerships. By using such approaches, future studies would be able to test additional differences, which we were unable to do in our single-industry domestic sample including the effects of industry differences, geographic location and nationality.

Furthermore, we suggest future research should focus more closely on exactly how attentional trade-offs could be accomplished and the way in which lock-in ossifies the innovative potential of network relationships, by closely examining these underlying mechanisms. This will require longitudinal, qualitative research.

6. Conclusion

We investigated embeddedness with suppliers and customers and its relationship with innovation. We claim two major contributions to the literature. First, we show that the management of network partnerships may return exponential benefits when focused on particular groups. That is, deep supplier and deep customer embeddedness provide firms with increased collaboration options which, coupled with the ability to manage them, can improve product or service innovation outcomes. Second, we find that the capability to switch attention between customers and suppliers and to fully leverage the innovation potential of both groups may be elusive. An attention switching capability could provide firms with a means to maximise the innovation potential of embeddedness across both groups, by enabling the allocation of finite managerial attention toward uncovering the most beneficial combinations between them. Firms lacking such an attention switching capability should be careful not to cultivate too many vertical network partnerships to avoid becoming a (non-innovative) cog in a network, beholden at both ends to others' requirements and unable to manoeuvre in innovative ways.

Acknowledgements

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Appendix A. Alternative model specifications

Below, we present a table of the study's main findings without repeated measures to demonstrate that the results do not alter substantively from those included in our main analysis. Note that there are two ways in which we can remove repeated samples from the overall sample: (i) exclude the repeat measure from 2012 [Ex. 2012]; or (ii) exclude the repeat measure from 2013 [Ex. 2013]. Both alternatives are shown for each of the DVs used in the paper in Table A1. The same substantive findings are obtained with or without the repeated measures, no matter from which year the repeat measures are excluded.

Table A1
Replicating the main analyses by survey year.

	PRODSERV		INNPROD		INNOVATOR	
	Ex. 2012	Ex. 2013	Ex. 2012	Ex. 2013	Ex. 2012	Ex. 2013
SUPP	− 0.72	− 0.06	− 0.43	− 0.21	− 0.60	− 0.40
SUPP2	0.61*	0.38+	0.47*	0.43*	0.70+	0.78
CUST	− 0.03**	− 0.07	0.018	0.40	0.63	− 0.30
CUST2	0.76	0.73+	0.42*	0.43*	0.97+	2.25+
SUPPCUST	− 0.98*	− 0.81*	− 0.73*	− 0.81*	− 1.44+	− 2.55+

We also compared the means (and proportions for binary variable comparisons) among the IVs and DVs between the 35 firms that responded in both years (shown in Table A2). Aside from one significant difference (SUPPCUST had a larger mean in the repeated sample in 2012), there were no significant differences between the different datasets in terms of the DVs and IVs. Importantly, the significant difference found with SUPPCUST was found to have no impact on the main findings (as shown in Table A1).

+ $p < 0.10$.

* $p < 0.05$.

** $p < 0.01$, two-tailed.

Table A2
Comparing means (proportions) among the 35 samples with repeated measures by year of survey.

	MEANS	
	2012	2013
PRODSERV	54.3	51.4
INNPROD	48.6	37.1
INNOVATOR	77.1	60.0
SUPP	0.8	0.4
SUPP2	2.2	0.8
CUST	0.5	0.1
CUST2	1.1	0.3
SUPPCUST	1.1*	0.1*
RD	45.7	57.1
LOGSIZE	1.7	1.8

P-values for binary variables calculated using the Chi-square statistic; *p*-values for means calculated using the Wilcoxin rank sum-test (due to non-normality).

Next we compared the means (proportions) among the IVs and DVs for the full sample, treating the repeated measures in two ways. In the first model (1) we compared independent and dependent variable means for the 2012 and 2013 samples while excluding the repeat measures from 2012. In the second model (2) we compared 2012 and 2013 samples while excluding the 2013 repeat measures (see Table A3). Again, we found that the means (proportions) among the IVs and DVs are not statistically different.

* $p < 0.05$.

Table A3
Comparing means (proportions) among the full sample.

	(1) Excluding repeats from 2012		(2) Excluding repeats from 2013	
	2012	2013	2012	2013
PRODSERV	64.7	53.9	59.4	55.1
INNPROD	61.8	44.2	55.1	47.8
INNOVATOR	79.4	64.4	78.3	66.7
SUPP	1.1	0.8	0.9	1.0
SUPP2	3.6	3.1	2.9	4.3
CUST	0.6	0.6	0.5	0.8
CUST2	2.1	2.2	1.6	3.2
SUPPCUST	1.5	2.2	1.3	3.2
RD	58.8	54.8	52.2	53.6
LOGSIZE	2.0	1.7	1.9	1.7

P-values for binary variables calculated using the Chi-square statistic; *p*-values for means calculated using the Wilcoxin rank sum-test (due to non-normality). *$p < 0.05$

Appendix B. Variables

Type	Variable (label)	Questions and items	Encoding
Dependent	Product or service innovation (PRODSERV)	Stem for all innovation related variables: "Has your firm introduced any of the following: technology, service, or managerial innovations in the past 3 years?" *Items in this measure:* *Technologically new or significantly improved physical product/technology (Yes/No)* *New or significantly improved 'service product' (Yes/No)*	Incidence of either type: yes (1), no (0)
	Innovation of any type (INNOVATOR)	*Items in this measure:* *Technologically new or significantly improved physical product/technology (Yes/No)* *Technologically new or significantly improved methods of producing a physical product/technology (Yes/No)* *Technological improvements in supply, storage or distribution systems for physical product/technology (Yes/No)* *New or significantly improved 'service product' (Yes/No)* *New method to produce and deliver your 'service product' (Yes/No)* *New organisational/managerial processes or marketing methods (Yes/No)*	Incidence of any type: yes (1), no (0)
	Product innovation (INNPROD)	*Items in this measure:* *Technologically new or significantly improved physical product/technology (Yes/No)*	Incidence: yes (1), no (0)
Independent	Supplier embeddedness (SUPP)	"Please indicate which type of collaboration/partnership excluding equity joint ventures you are/were engaged in and with whom? Multiple answers are encouraged" (Each row has the following yes/no options: suppliers, customers, higher education/research institutes, private research institutes/consultants, and firms in your line of business.) *Management and staff development (S1)* *Gaining access to (or spread costs of) new equipment, technology or information sources (S2)* *Purchasing jointly materials or inputs (S3)* *Streamlining the supply chain (S4)* *Outsourcing aspects of your business operations (S5)* *Improving and sharing infrastructure (roads/pipes/rails)(S6)* *Development of specialist services/products required by customers (S7)* *Sharing research and/or development act (S8)* *Involvement in collaborative R&D activities funded through grants (S9)*	Sum of modes used with suppliers (9 max). Cronbach Alpha = 0.722

	Customer embeddedness (CUST)	*Management and staff development (C1)* *Gaining access to (or spread costs of) new equipment, technology or information sources (C2)* *Purchasing jointly materials or inputs (C3)* *Streamlining the supply chain (C4)* *Outsourcing aspects of your business operations (C5)* *Improving and sharing infrastructure (roads/pipes/rails)(C6)* *Development of specialist services/products required by customers (C7)* *Sharing research and/or development act (C8)* *Involvement in collaborative R&D activities funded through grants (C9)*	Sum of customer modes (9 max). Cronbach Alpha = 0.762
	Deep customer embeddedness (CUST2)	*See supplier embeddedness for stem and underlying items*	Customer embeddedness term squared
	Deep supplier embeddedness (SUPP2)	*See supplier embeddedness for stem and underlying items*	Supplier embeddedness term squared
	Vertical embeddedness (SUPPCUST)	*See supplier embeddedness for stem and underlying items*	CUST × SUPP multiplication
Controls	RD (research and development)	"Did your firm engage in RESEARCH AND DEVELOPMENT (R&D) in the last financial year?" *(Yes/No)*	Incidence: yes (1), no (0)
	LOGSIZE	"Provide the best estimate of your firm's workforce as full-time equivalents (FTE)"	Natural log of response
LCA support variables	Search breadth (BREADTH)	"Please indicate the importance of the following external sources of information for your firm's innovation activities during the last 3 years. Please circle the appropriate number in each row." Likert scale: Not a source (1); An insignificant source; (2) a common source (3); very significant source (4); crucial source (5) *Suppliers of equipment, materials and components* *Clients or customers* *Competitors in your line of business* *Consultancy firms* *Financiers (e.g. venture capitalists)* *Universities/higher education institutes* *Government or private non-profit research institutes* *Patent disclosures* *Professional conferences, meetings, professional journals* *Fairs/exhibitions* *Trade associations, chambers of commerce* *Computer-based information networks*	Sum of sources used ranked 2 or higher (Max 12)
	Search depth (DEPTH)	*See breadth description for underlying variables*	Sum of sources used ranked 4 or higher (max 12)
	Total collaborations (TOTCOLLAB)	*See supplier embeddedness for stem and underlying items*	Sum of modes used with any of five types (range: 0 to 45)
	Service firm (SERVICE)	"Please indicate the Oil and Gas value chain position that BEST characterises the activities of your firm" options: "(a) Oil and gas Operator (upstream exploration and production or downstream refining and processing and sales) (b) Contractor (e.g. oil field services, engineering, construction, logistics, maintenance) (NOT suppliers of special material/equipment/services) (c) Suppliers of material, equipment and services (basic materials, specialised products and services (e.g. 3D seismic))"	Encoded 0 if 'oil and gas operator' was yes and 1 if else to indicate a service firm position.

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