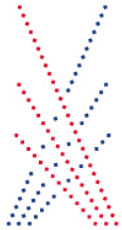

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Open innovation and the problem of capability remoteness

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Open innovation is the process through which a focal organisation engages in search, adaptation and adoption of externally developed knowledge to enhance the effectiveness and value of its innovation activities (West and Bogers, 2014). As such open innovation (OI), challenges the central tenets of the resource-based view (RBV) in two respects. First, RBV assumes some degree of ownership (Dierickx & Cool, 1989) or control (Barney, 1991) of valuable, rare, inimitable and non-substitutable (VRIN) resources, including knowledge and capabilities to gain competitive advantage in an industry. Ownership and control over resources is assumed to be critical not only for building strategy for competitive advantage (Wernerfelt, 1989) but also for developing dynamic capabilities that help create, extend or modify the resource base of the firm (Helfat et al., 2007). However, ownership and control over certain resources can also be plagued by problems of inertia and inefficiency, requiring to "destroy part of its existing resource base by selling, closing, or discarding it" (Helfat et al. 2007: 6). Second, the very same resources that create advantages are plagued by the double edge sword of causal ambiguity. On one hand, RBV considers causal ambiguity as a safeguard against rivals' attempts to imitate the firm's resources when the link between those resources and competitive advantage is inexpressible (due to the high degree of tacitness in the composition and use of resources) or poorly understood, thus preserving heterogeneity (Barney, 1991). On the other hand, if the focal firm itself cannot understand or for other reasons cannot express what resources and how their uses serve as basis for competitive advantage, using those resources as competitive basis will be bound to uncertain outcomes (Peteraf, 1993).

While generally conceived as a continuum, in its strict sense OI expands beyond the limits of ownership and control through the provision of resources that lie outside the boundaries of the firm (Dahlander and Ghann, 2010). Firms that engage in OI will access novel information and solutions to their (or specific customer groups') problems at the cost of identifying and extracting the knowledge needed from key experts, customer groups or communities (Chesbrough, 2003) as well as governing the platforms and mechanisms through which the firm accesses this knowledge (Felin

and Zenger, 2014). In this regard, OI reorients the liability of ownership and control to an opportunity of inclusiveness and participation (Hautz et al., 2017).

Further, because firms can take variable steps of openness they can reveal internal critical resources gradually to outsiders invited to collaborate on innovation projects (Henkel et al., 2014). This allows firms to evaluate the degree of value gained from OI, while avoiding potential risks associated with sharing information or ideas to outsiders. In doing so, firms can gradually resolve the causal ambiguity underpinning their resource base, hence re-establishing control over the sources of competitive advantage. However, OI research has particularly identified that access to critical resources will be contingent on sophisticated social mechanisms imbued by trusting relationships (Flemming and Waguespack, 2007), sense of reciprocity (Boudreau and Lakhani, 2009), motivation (Frey et al., 2011), and the use of bargaining power by the resource owner (Gambardella and Panico, 2014).

Given these opportunities for OI to address some of the most critical aspects of the resource and dynamic capabilities views respectively, it seems promising to bridge this conceptual gap by combining these seemingly disparate bodies of literature. Such a project will help advance not only the understanding of some key mechanisms through which OI can address the longstanding challenge of strategic drift but also how to reach capability thresholds for innovation and change. Against this background, the aim of this study is to answer the question of how OI can support a firm's dynamic capabilities. More formally, the present study is guided by the following research question: *How can open innovation help bridging a firm's capability gap?* To answer this question, we conducted an in-depth study of 3 new product development (NPD) projects that utilised OI practises in a UK manufacturing organisation. Our study draws on a range of data sources including archival and field data, to develop a substantial understanding of the underlying mechanisms of OI that support the firm's dynamic capabilities.

Our research revealed that when a capability gap exists i.e., there is a difference between what a company 'knows' and what a company 'needs to know', then OI is an underlying mechanism that can facilitate knowledge transfer from external actors to close this gap. OI can, therefore, serve as a means of minimizing the firm's capability distance to remote technological fields and thereby reinstate a capability proximity with its environment. However, this will depend on the firm's capacity to overcome social complexities to locate, access, and transfer knowledge from outside the firm boundaries. This is impacted by factors including the level of resource investment, perceived risk and reward associated with the corresponding OI engagements. The next section will explore the theoretical underpinnings of this study and the process of OI in practise in more depth, to gain a

deeper understanding of the underlying mechanisms of OI that support a firm's dynamic capabilities. Subsequently, we move on to present the research site and methodological and analytical choices made before we move on to presenting our findings. Finally, we discuss the findings and conclude with some implications for theory and practice.

Theoretical Framework

Firm resources and dynamic capabilities

Historically, the strategic management field was dominated by theories rooted in economics. During this period, it was argued that by examining market structures and the nature of competition, it was possible to position a firm relative to competitors, to achieve a competitive advantage (Porter, 1980). However, the static nature of this exogenous market-based approach resulted in research that examined the firm as a collection of resources, that could be configured to exhibit characteristics that were valuable, rare, inimitable, and not substitutable (Barney, 1991). In other words, it was possible for firms to shape external markets through the configuration of firm resources to develop novel solutions such as those generated through product innovations. Firm resources were assumed to consist of both tangible and intangible assets such as information, (tacit) knowledge, organisational processes, and capabilities. The resource-based view was constructed on the belief that in a given industry, the resources a firm owned or controlled were heterogeneous, and those resources were not mobile across firm boundaries (Barney, 1991). However, RBV is poorly devised to address the question of how competitive resources can keep pace with technological advancements and shifts in market needs and demands and thus stay abreast of strategic change.

Building on the resource-based theory of the firm, the dynamic capabilities framework emerged to answer the question of how a company can create and maintain a competitive advantage in changing environments that give rise to extensive market competition (Teece et al., 1997). Focusing on firm-specific capabilities, a firm's dynamic capabilities govern how the firm "integrates, builds, and reconfigures internal and external competences to address changing business environments" (Teece et al., 1997: p516). However, at this time, the literature did not have an answer to the question of how dynamic capabilities were developed and how they evolve (Zollo and Winter, 2002). Later research by Winter (2003: p991) defined the concept of a capability as "a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization's management a set of decision options for producing significant outputs of a

particular type". Furthermore, capabilities follow a life-cycle of progression from founding to development, prior to reaching maturity (Helfat et al., 2003). The founding and development stages are significant to organisations that innovate, since they ultimately determine the success or failure of the development of a capability. The founding of a capability requires a clear objective and a group or team with sufficient leadership, to transition to the development stage (Helfat et al., 2003). This conceptualisation of the capability is supported by human capital in the form of individuals knowledge skills and experience and social capital that can be gained from interactions with external actors (Helfat et al., 2003). Subsequent to founding, the development stage is assisted by search efforts and experience accumulation, driven by the requirement to accomplish the end result (Helfat et al., 2003). Ultimately the success of capability development is reliant on the firm's determination of activities necessary to achieve the end result.

The concept of dynamic capabilities was further clarified by Winter (2003) who highlighted a distinction between ordinary capabilities and dynamic capabilities. Ordinary capabilities can be thought of as capabilities that permit a firm to perform the production and sale of existing products whilst in equilibrium (Winter, 2003). Contrastingly, dynamic capabilities "operate to extend, modify, or create ordinary capabilities" (Winter, 2003: p991). Moreover, dynamic capabilities were classified as higher-order or second-order. Higher-order dynamic capabilities encompass the processes of sensing, seizing and transformation and ultimately direct second-order capabilities (Teece, 2018a). These processes can be assisted by configuring organisational management and processes in ways to detect likely future avenues and through the division and implementation of supporting business models (Teece, 2018a). In contrast, second-order dynamic capabilities result in the adjustment and recombination of ordinary capabilities through processes such as NPD (Teece, 2018a). Therefore, the founding stage of an ordinary capability is assisted by the high-order process of sensing, through the identification of exogenous market conditions, and accordingly, directing internal activities such as research and development and new technology identification in anticipation of market opportunities (Teece, 2007, Teece 2014). Subsequent to founding, the development stage is assisted by the second-order process of NPD. Whether the organisation can continually generate value from NPDs will ultimately be determined by the higher-order processes of seizing and transformation.

A key consideration of the dynamic capabilities framework is the challenge to keep abreast with changes in the firm's technological and environmental fields (Helfat et al., 2007). For when firms' lack the capabilities of implementing or addressing strategic changes imposed on them from innovative market actors through the introduction of new technologies or demands/needs from

customers, they are liable to strategic drift. Such a drift is the prime source of capability remoteness, or the tendency of a firm's capability configuration to become increasingly inadequate or obsolete to the current technological state of the industry in which firms vie for a position. Hence, strategic change in the firm's resource base is at the heart of the dynamic capability framework. More recently, research on the application of the dynamic capability framework suggested the role of knowledge generation and OI in supporting the framework (Teece et al., 2016). However, we are yet to fully understand how the underlying mechanisms of OI and knowledge creation can support a firm's dynamic capabilities. Consequently, the remainder of this section aims to investigate the role of OI and knowledge creation in the context of dynamic capabilities.

Open Innovation and Knowledge Creation

In a period of rapidly changing markets, the ability to generate new products is essential to organisations to ensure strategic fitness in its resource and capability base. Product innovations require the creation of new knowledge that can be applied in such a way to deliver value to customers. The closed innovation approach, where ideas for innovations were generated inside the firm can inhibit a firm's ability to innovate. For instance, one difficulty with the knowledge required to innovate is that it can be fragmented among specialists throughout different organisations. The RBV framework further recognizes the mutual benefit and risk of social complexity and causal ambiguity, where the former implies the social and historical situatedness of innovation and the latter the difficulty of understanding or explicating the causal links between resources and competitive advantage (Barney, 1991). While both of these firm specific conditions compound the difficulty of imitating resources and moving them across organisational boundaries by competitors, they may also inhibit firms that control these resources to adequately leverage on them in competitive situations (Peteraf, 1993). Furthermore, internally developed knowledge may be plagued not only by high degrees of redundancy but also a laborious search activity with unpredictable outcomes given the difficulty of identifying pockets of salient and transferrable expertise within the organisation (Kogut and Zander, 1996). Critics have also raised doubts about firms that are overly reliant on internal R&D, prompting the need to consider "the right balance between internal and external sources of innovation" (Dahlander and Gann, 2010: 701). This has increasingly influenced organisations to consider the search for relevant knowledge outside its boundaries. Hence, adopting an 'open' approach to innovation can help overcome these limitations by providing benefits through linkages with external actors.

Open Innovation has been defined as “the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively” (Chesbrough, 2008 : p1). The OI approach draws on a wide range of external actors as a means to improve innovation performance (Laursen and Salter, 2006). Consequently, OI increases the quantity of accessible specialist knowledge sources. The external sources that support innovation through the provision of knowledge inflows can include, but are not limited to suppliers, customers, competitors, and universities (West and Bogers, 2014). Leveraging the resources and knowledge of suppliers and customers has been found to enhance firm performance (Cao and Zhang, 2011). Furthermore, practising OI has been found to positively impact the financial performance of R&D projects (Du et al., 2014) and enhance new product innovativeness and success (Cheng and Huizingh, 2014). This could be a consequence of information sharing with customers, that has the potential to provide opportunities to learn about future requirements, enabling the firm to focus internal research efforts supporting the development of novel solutions. Moreover, information sharing with suppliers generates opportunities to learn about new technologies and product innovations and possible utility in novel markets. Thus, when viewed from the perspective of dynamic capability, information gained through OI supports the higher-order sensing process, and second-order process of NPD due to the aforementioned reasons.

However, to gain utility from knowledge inflows, a firm must possess capabilities to absorb external knowledge, and use that knowledge to develop new products that create value for customers. The ability to recognise valuable information from outside the firm boundary, absorb and integrate information with the existing knowledge base, then apply the information to commercial ends has been defined as the firm’s absorptive capacity (Cohen and Levinthal, 1980). More recently, AC was conceptualized as capacities (capabilities) for recognition, assimilation and exploitation, that have been associated with enhancing the effectiveness of OI (Zobel, 2017). The recognition capability is underpinned by external scanning and strategic assessment and supports the exploration, identification and valuation of new external knowledge (Zobel, 2017). OI provides opportunities to enhance the firm’s capacity for recognition through purposive inflows of knowledge from external sources. However, possessing a capacity for recognition does not guarantee the utility of knowledge, hence the role of assimilation. While these capabilities are necessary, they are not sufficient for addressing strategic drift.

Firms exposed to capability remoteness due to strategic drift must possess capabilities to efficiently process information and create new information and knowledge (Nonaka, 1994). Early research on knowledge creation highlighted a distinction between explicit and tacit knowledge (Nonaka, 1994).

Explicit knowledge has been classified as knowledge that can be uttered, formulated in sentences, and captured in drawings and writing (Nonaka, 2006 : p1182). Explicit knowledge is codifiable making it easier to express and record, and it is relatively less costly (Garicano and Wu, 2012). On the other hand, tacit knowledge has been described as being acquired and expressed through the human physical experiences, senses, movements, skills (Polanyi, 1966), and intuition or implicit rules of thumb (Nonaka, 2006 : p1182). Tacit knowledge is hard to formalize, express, classify and transfer, making it relatively costlier. The relationship between tacit and explicit knowledge has been conceptually distinguished along a continuum (Nonaka and Krogh, 2009), so rather than a definitive classification of tacit or explicit knowledge, knowledge can be referred to in relation to tacitness or explicitness. Moreover, the interaction between knowledge with high levels of tacitness and knowledge with high levels of explicitness can be explained by the knowledge conversion process (Nonaka and Krogh, 2009). There are four modes of knowledge conversion that have been classified as socialisation, combination, externalisation, and internalisation (Nonaka, 2006). Each mode experiences some level of interaction between explicit and tacit types of knowledge. To explain this further, socialisation is associated with the transfer of tacit to tacit knowledge. In the context of NPD, socialisation is facilitated through shared experiences and on the job training. Comparably, externalisation is the transfer of tacit to explicit knowledge, such as sharing an idea for a new product using a tangible concept or proposal. Internalisation is the conversion of explicit knowledge to tacit knowledge. For example, reading technical literature about a product component, then applying the knowledge in a practical development situation. Finally, combination is the transfer of explicit to explicit knowledge and can be understood as sorting, adding or combining different types of explicit knowledge. Of course, knowledge combination is likely to involve some degree of tacit knowledge both in its content and its process of execution.

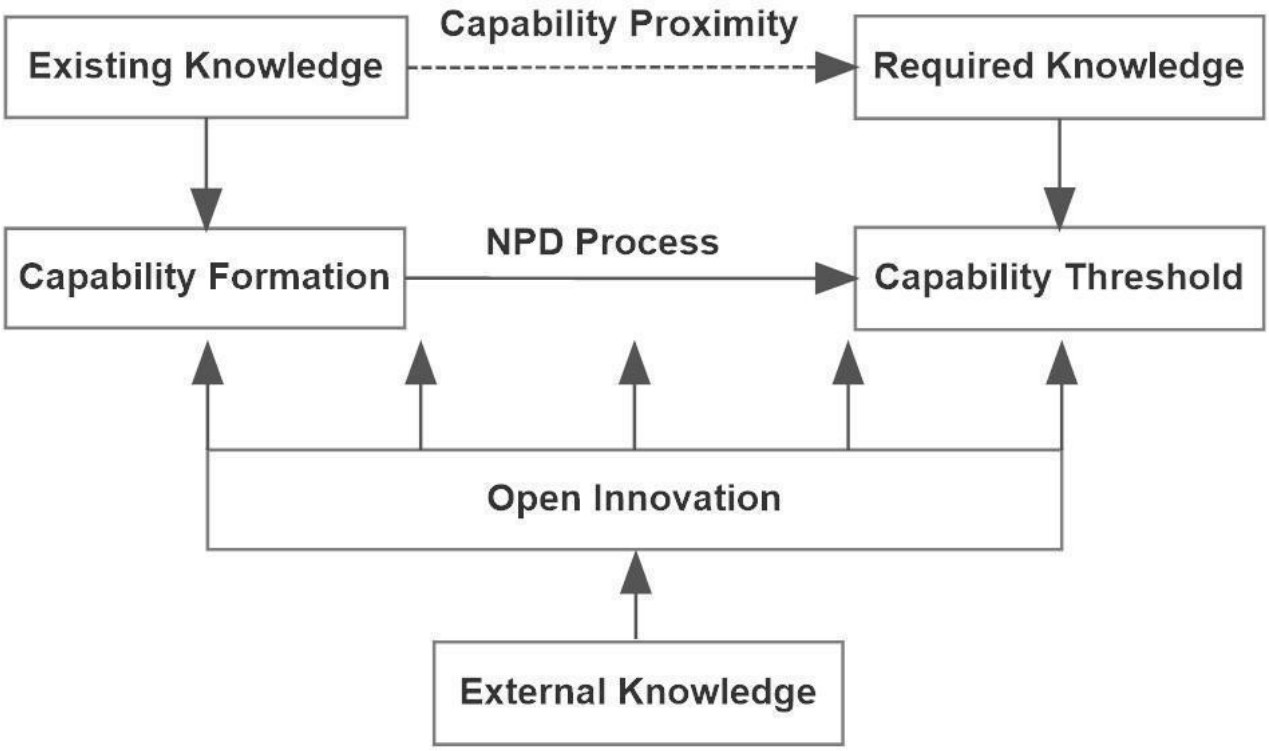
The process of NPD can be impacted by the knowledge conversion process during OI in at least two ways: First, OI provides opportunities for different modes of knowledge conversion, due to interactions with external knowledge sources that vary in expertise, explicitness and tacitness. Second, knowledge accessed from customers and suppliers is supported by a pre-existing knowledge base due to industry familiarity that can potentially reduce the cost of knowledge exchange and increase the likelihood of socialisation and externalisation, resulting in the successful transfer of knowledge with high levels of tacitness.

Development of Conceptual Model

We posit that open innovation supports higher order dynamic capabilities through inbound knowledge flows from suppliers, customers, competitors and other stakeholders. These knowledge flows have the potential to highlight opportunities to enhance existing capabilities through knowledge conversion and feedback, that can lead to the generation of ideas for novel capabilities. The process of NPD is considered a second-order dynamic capability, supported by external knowledge flows that constitute OI practises. The NPD process begins after the requirement for an innovation is conceptualized through the sensing mechanism (Teece, 2007), cementing the formation of a capability through creation (e.g., radical product development) or modification (e.g., an incremental product development), to create value for customers. Subsequently, during the development process, it is possible to access existing knowledge stock to determine whether the organisation possesses the knowledge required to achieve an arrangement of activities necessary to reach the capability threshold, which, in this instance, would encompass a fully developed new product. Alternatively, if the existing knowledge stock does not offer a suitable arrangement of activities to reach the capability threshold, OI facilitates access to external knowledge sources that will ultimately vary in the degree of explicitness and tacitness. However, this will be at the cost of identifying and extracting the knowledge needed from key experts, customer groups or communities (Chesbrough, 2003) and will ultimately impact the efficiency of the NPD process. A key determining factor of the amount of knowledge sought from external sources is the distance, between the existing stock of knowledge, in terms of amount, complexity and novelty of tacit and explicit knowledge embedded in a firm's focal capability and the aspired capability. For example, in a study of the auto industry's transition from internal combustion engines to electrical engines and other forms of auto transportation, Teece (2018b) illustrated the potential capability gap between existing capabilities and the capabilities needed during such technological transition, to satisfy market demand. However, neither Teece (2018b) nor others have elaborated on the concept of capability distance to aid further utility. Consequently, we propose the concept of a capability proximity as the difference between the existing knowledge of an organization and required knowledge to determine the set of activities necessary to reach the threshold of a new capability or modify an existing capability. We view the process of NPD as a means of facilitating capability development (e.g., through a new product that is manufacturable and saleable), which has a beginning point (i.e., ideation and formation), end point (i.e., tested and developed) and consisting of a set of activities necessary to transition from the beginning to end point. Furthermore, the process of capability development is not limited to a single path from formation to threshold. In

other words, like a game of chess, different manoeuvres can be performed (even repeatedly and with some degree of precision and accuracy in its resulting effect) to achieve victory over the opponent. The implication of this is that the dynamic capability that underpins capability development in the form of a new product, can result in a costly development process, depending on the sequence of actions taken relative to reaching the capability threshold. Our conceptual model (Figure 1) illustrates the relationships between these variables.

Figure 1 - Conceptual Model



Research Design and Methods

The aim of our research was to develop an understanding of how OI can help to bridge a firm's capability gap by supporting a firm's dynamic capabilities. More specifically, how external knowledge flows can contribute to new capabilities and the underlying knowledge transfer mechanisms. Accordingly, our research adopts a longitudinal embedded multiple case design (Yin, 2014) that uses in-depth archival and field data to track closely the activities and processes performed by organisational actors of a small to medium sized firm to engage external actors in the focal firm’s innovation activities in pursuit of reaching the capability threshold. An embedded multiple case approach was an appropriate choice of research design because it offered an in-depth inquiry into a specific and complex phenomenon, set within its real-world context, and yet allowing replication where each case can serve to confirm and disconfirm inferences drawn from the other

(Yin, 2014). This approach typically generates more robust and generalizable findings than single cases (Yin, 2014). Our design draws on three separate cases, or innovation projects involving OI to achieve capability thresholds.

Our unit of analysis is at the project level which is an appropriate way to establish an accurate account of how open innovation contributes to capability development through the process of NPD. We conducted a longitudinal study of the NPD process within a small to medium enterprise (SME) UK manufacturer. This was deemed appropriate for studying OI for several reasons: First, the organisation frequently engages in NPDs owing to its presence in a diverse range of markets. For example, between the years 2017 and 2018, the organisation had been involved in 197 and 196 development projects respectively, with 28.6% leading to sales. Second, owing to a diverse product portfolio is a requirement for an extensive supply chain, offering access to a vast range of suppliers. Moreover, a large customer-base requires an external sales force that is tasked with gaining new business by gathering information on external development opportunities and market movements. Consequently, the majority of the organisations NPD projects consist of input from external actors, including customers and suppliers.

To identify relevant NPDs and provide a balanced view, we selected a cross section of projects that met the following criteria: projects were recent, had disparate driving forces, included significant input from external actors, had fully cycled the process from formation to threshold, and had resulted in sales. This satisfies the requirement that OI practices were engaged throughout the process, and that the development had concluded, ensuring all available engagements with external actors throughout the process had been captured. We purposefully sampled (Patton, 2001) and analysed three cases of NPD that began with varying levels of market demand for the product being developed. The idea for the first development was driven from within the focal firm and emanated from a loss of business to competitors, due to inferior product offerings in the market domain. This development illustrated a capability gap and competitive disadvantage concerning the manufacturer's offerings and market requirements. The second and third developments emanated from external market forces. The second development manifested as a requirement for a product that would enable external actors to compete in existing markets at lower cost, providing a competitive advantage to their business. The third development was raised due to a customer’s existing supplier, utilizing assets that were no longer conducive to the product being manufactured. Subsequently, technical and manufacturing issues were frequently experienced and served to drive both the customer and supplier to pursue manufacture elsewhere. The disparate forces driving these innovations demonstrate cases with some contrast in the sense of clear market forces in addition to

internal forces. Thus, providing insight into different sources of knowledge and any factors that may or may not influence knowledge access.

Research Methods

The first author was acting as researcher practitioner and consequently had frequent access to the organisation throughout the research duration. We obtained a high-level understanding of the projects from the organization's internal development system. The development system records all the documented activities that took place during the project including meetings with customers, and technical and cost requirements that were documented from those meetings. This was used as a framework for producing an NPD timeline, whereby depth could be added to the processes that had been followed through subsequent quantitative and qualitative data capture utilizing the actors involved.

Following this, we obtained all recorded communications associated with the corresponding product development from within the organization (Table 1). This consisted of emails between internal staff revealing any attempt to gain knowledge from the existing knowledge base, emails between internal and external staff revealing any attempts to gain knowledge from an external knowledge base, and finally, documented meetings and reports associated with the development. Meeting minutes and reports ranged from brief summaries, to more comprehensive multiple page documents.

Table 1 – Communications Obtained and Type for each NPD

		NPD One	**NPD Two**	**NPD Three**
Emails	*Pages*	231/231	92/92	104/104
Meeting Minutes	*Documents*	5/27	3/17	2/2
Reports	*Pages*	16/25	2/28	4/18
Informal discussions	*Internal*	4	4	6
	External	1	1	--

Interviews	*Internal*	--	3	3
	External	2	1	--

Subsequent to this, informal meetings were held with internal actors that had been involved in the development process including project leaders, technical and production staff, and external sales staff, to discuss and validate the data that had been captured and reveal the driving forces behind activities that had involved external actors.

In order to develop a greater understanding of NPD projects and how OI had influenced the process, we conducted semi-structured interviews with a range of staff that included project leaders and external sales. The interviews lasted a duration of six hours in total, during which, a comprehensive discussion took place. This helped to reveal the driving forces that had led to external input, and more importantly, how the external input had impacted the NPD. Some of the questions posed during the interview process included 1.) *"What reasons, if any, led you to seek information from an external organization?"*, and 2.) *"In what ways, if any, did external input change your behaviour or actions during this interaction?"*. During the subsequent data analysis, we conducted further semi-structured interviews with the project leaders to shed light on key concepts that had emerged. This was supported by telephone interviews that were conducted with external actors that had a substantial input into the NPD process.

Analysis Method

Our research adopts elements of qualitative and quantitative research as defined by Ketokivi and Choi, (2014 : p233), whereby quantitative research "examines concepts in terms of amount, intensity or frequency", and qualitative research "examines concepts in terms of their meaning and interpretation in specific contexts of enquiry". Initially, we used a quantitative approach to establish a grounding of the phenomenon being studied. At this stage, we reviewed documents associated with NPD projects, and captured the amount and frequency of communications with external actors. Following this, a qualitative approach was used to add granularity to the iterative nature of activities employed during the NPD process. This consisted of interviews with project leaders, internal staff and external actors involved in each process, to develop a greater understanding of the activities and behaviours that had occurred.

Our analysis focused on the three NPD projects. In step one, we established the purpose and engagement types of each interaction with an external actor, that had been identified as a component of each NPD process. Identification of the purpose type had the effect of revealing the driving force (i.e., the why) behind the OI engagement, raising the question of how and what was sought from external actors. The engagement category was developed to deepen the purpose category by way of understanding the means and type of engagement employed during OI. To develop a more complete understanding of the engagement and how external actors had impacted the NPD, we developed classifications for the resulting input and behaviour modifications associated with all external activities. The criteria used throughout this process (Table 2) were developed in correspondence with the project leaders, and continually refined during subsequent interviews and discussions that were conducted for each NPD. Details from each correspondence were again matched with the classifications and subsequently inserted these into the framework representing the NPD timeline. At this stage, activities that had been deemed significant to reaching the capability threshold by the author and the NPD project leaders were labelled iterations.

Table 2 – External Inputs Impacting NPD

	NPD One	**NPD Two**	**NPD Three**
Purpose Types (Rationale behind OI)	Characteristics Market Potential	Characteristics Market Potential	Characteristics Feasibility Market Potential
Engagement Types (Means and types of engagement)	Information Sharing Co-Developing Resource sharing	Information Sharing Co-Developing Resource sharing	Information Sharing Co-Developing Resource sharing
Resulting Inputs	Technical Practical Costing Supply	Technical Costing New Query Physical Sample	Technical Practical Costing Supply Projections New Query Product Sample
Behaviour Modification	Change Component Modify Component Order	Change Component Modify Component Order	Change Component Modify Component Order

	Modify Manufacturing Process Fundamental Product Change Thinking Information Gathering	Information Gathering Thinking	Modify Manufacturing Process Fundamental Product Change Information Gathering Product Specifications

In step two, the types of knowledge that had contributed to each significant engagement were ranked (Table 3). This was achieved by ranking each iteration to the overall project in terms of the significance and establishing the associated knowledge complexity associated with the iteration. The project leaders scored each iteration in isolation, and subsequently, the author met with the project leaders to gain a better understanding of the reasons behind the scoring.

Table 3 – Measures of Significance and Knowledge Complexity of External Inputs

	Score	**Description**
Significance	1	No influence on the success of the development
	2	Slight influence on the success of the development
	3	Moderate influence on the success of the development
	4	High influence on the success of the development
	5	Absolutely critical to the success of the development
Knowledge Complexity	76-100	Open Access, easily accessible, available in technical brochures, literature, websites, etc.
	51-75	Restricted or subscription access (professional bodies / trade associations / universities, etc.)
	26-50	Explicit or proprietary knowledge accessed via a corporate relationship (e.g., customer or supplier)
	1-25	Tacit knowledge accessed via personal relationship (e.g., key individuals in customers or suppliers)

In step three, we used the data captured to plot a graph of each iteration associated with each NPD, and the corresponding significance and knowledge complexity of the external input. This had the

effect of revealing any relationships between the type of knowledge accessed i.e., open, proprietary, tacit or explicit, and the level of contribution to the success of the overall product development. Following this, we performed an analysis of the initial semi-structured interviews that were conducted with the project leaders and external sales. This included transcribing the interview data, reading through the transcripts several times, and noting any themes that had occurred. At this stage, several themes had been highlighted as key conceptual terms. We extracted key quotes from the transcripts and used them to enrich the subsequent reporting of findings. Following this, we performed an analysis of the final semi-structured interviews with project leaders and telephone interviews with external actors, whereby the data was used to further clarify conceptual terms and ensure validity and integrity of our findings.

In step four, we employed an abductive approach (Ketokivi & Mantere, 2010), moving back and forth between our findings and the literature to better ground our concepts with existing concepts wherever possible. Hence, the concepts introduced in the following section illustrating the process of capability gap closure, that is, the process through which the organisation reached the capability threshold are combinations of existing theoretical concepts and inductively generated terms based on terms used by the actors involved in the NPD.

Findings & Analysis

Results from the analysis are presented according to development, followed by a comparison of the NPD processes with consideration to the capability proximity. This section concludes with the introduction of a framework for restoring a capability proximity with open innovation and the development of theoretical concepts formed during the latter stages of the analysis. In this section, we refer to the organisation responsible for the NPD projects as Alpha. Similarly, we use pseudonyms to reference specific external actors to protect their anonymity.

NPD One

The first development emanated from the loss of a significant account that amounted to approximately 10% of Alpha's total turnover. It was reported by one of Alpha's sizeable customers (C1) that Alpha's product was inferior in terms of cost, ease of use and durability, which suggested that there was a clear technological gap between Alpha's product and a competitor's direct equivalent. Regaining this account would require the development of a new product that not only

matched the features and characteristics of the direct competitor's material, but also provided additional properties that would create extra value for C1. Historically, Alpha had struggled to develop a product that would compare with the competitor's owing to a lack of technical skills within the organisation. However, an external consultant had been employed recently on an unrelated project and the ensuing tacit knowledge transfer provided Alpha with confidence to exploit this newly acquired knowledge and begin the required development. Nevertheless, at the beginning of this project, Alpha still had a limited understanding of the raw material technologies that were used throughout this market. The project leader had scoured multiple industry leading suppliers' websites for technical literature, but this did not provide a breakthrough. In one report, it was stated by the project leader *"We have manufactured somewhere in the region of 60 [products] and not achieved a product we deem suitable for end use"*. Consequently, the project leader had sought external input: *"We visited some development chemists at [supplier] and are working closely with them to resolve these challenges"*. During meetings with suppliers, externalization of knowledge had been supported through the provision of tangible examples to illustrate the technical difficulties being experienced that could not be effectively communicated via email and telephone conversations.

The duration of NPD One was approximately 14 months (ref. Table 4). The development consisted of 228 documented activities, of which, there were 43 iterations (ca 19%) where external input had supplemented the internal knowledge base, resulting in a modification to internal behaviour. Each modification provided some level of contribution to the NPD albeit with differing levels of significance.

In terms of knowledge complexity, there was a reasonably even distribution of tacit to explicit knowledge obtained from external sources amounting to 22 tacit and 21 explicit iterations respectively. However, it did appear the critical contributions to the overall product development were a consequence of accessing knowledge with higher levels of tacitness. Despite this, explicit knowledge did provide a highly influential contribution the overall success of the product development, indicating both types of knowledge contributed to the success of this NPD project. To explain this further, initially, the project leader emailed a query concerning a significant issue being experienced. In response, the technical expert noted: *"Well, this is not so easy to answer"* and after some elaboration, it was stated *"there is maybe a better solution"*. The technical expert later visited Alpha, where the project leader was introduced to a novel type of raw material. This new knowledge was subsequently fed back to another supplier, who was able to provide a product with similar properties. However, the cost of the raw material would price Alpha's product out of the

existing market. Consequently, the supplier was willing to work with Alpha by reducing the cost of the raw material, offering a solution to this iteration.

These new technologies possessed desirable properties that appeared to offer a resolution to many of the limitations of Alpha's existing product. However, at this point, it was still necessary to integrate the innovative raw material with other raw materials to generate a solution that could be utilised to add value to C1. Interestingly, during the NPD process, 10 iterations appeared to cycle between initially seeking knowledge with higher levels of explicitness, prior to switching to knowledge with higher levels of tacitness.

NPD Two

The second development began when one of Alpha's external representatives contacted a potential new customer during a cold call visit. The prospective customer was experiencing technical issues with a competitor's product. Moreover, the representative was aware through other customers that the geographical area offered significant opportunities in the agricultural market and that Alpha did not have a suitable product offering for this market. The market demand was clear and the prospective customer's ambitions for growth were being limited by its supplier's capabilities. The development requirement was for a product that had technical properties to facilitate a specific application method in addition being inexpensive.

The capability gap associated with this development was perceived by Alpha to be less than for NPD One owing to an existing Alpha product (P) that possessed similar technical properties. Despite this, the project leader had noted *"We needed a product similar to P that would go through [the process], but at a lower cost."* Alpha were not aware at this time of how the cost of manufacturing P could be reduced so it was necessary to involve its suppliers in exploring alternative raw materials. During the development, the supplier who provided the raw material for P was contacted to see whether they had a lower cost raw material with similar application properties to the raw material used in P. Initially, the supplier had been reluctant to share this information due to a perceived risk of losing the existing business. Consequently, the project leader *"had to assure them this was a brand-new product and that we were going after new business".* The supplier was able to recommend a raw material with similar technical properties to the raw material utilised in P, but at a lower cost.

The duration of NPD Two was approximately 14 months (ref. Table 4). The development consisted of 79 documented activities, of which, there were 12 iterations (ca 15%) where external input had supplemented the internal knowledge base, resulting in a modification to internal behaviour. Each modification provided some level of contribution to the NPD albeit with differing levels of significance. The knowledge complexity throughout this development consisted of 6 iterations sourcing knowledge with higher levels of tacitness, 3 iterations sourcing knowledge with higher levels of explicitness, and 3 iterations sourcing knowledge that was openly accessible. The two most significant contributions to the overall project indicated more tacit knowledge access. However, knowledge with higher levels of tacitness did not always result in significant contributions to the project. Furthermore, openly accessible knowledge also provided a significant contribution to the overall development.

In addition to technical literature and safety data, the prospective customer had provided tangible samples of the competitor's product for benchmarking purposes. Further customer involvement led to physical trials with the products and the project leader noted *"there was a customer feedback loop where we send in a sample, and they gave us some nice feedback, then we made some improvements and developed another sample".* This incremental refinement process led to the perfect balance of technological properties whilst achieving the cost requirements for the product. Thus, suggesting an efficiency of process in the extraction of relevant information from external actors. The project leader also provided some insight into the difficulty associated with the extraction of tacit knowledge *"it can be difficult pulling information from them (customers) and it might not be technically based, it might be them not being able to describe in words what they want".*

NPD Three

The third development began when a manufacturer of similar products (Gamma) contacted Alpha's R&D Manager with an enquiry about Products X and Y, that Gamma were currently manufacturing on a recurrent schedule for their customer C2. Gamma were no longer interested in manufacturing X and Y owing to technical difficulties being experienced during manufacturing that Gamma could not resolve. The project leader revealed products X and Y had similar technical properties to existing products within Alpha's portfolio, which suggests that the capability gap was less than for NPD One and comparable to NPD Two. Gamma provided Alpha with product formulations to determine whether X and Y were manufacturable on Alpha's machinery. The project leader noted

"from the start of the development, Gamma gave us information about C2 and said we could deal directly with them". This was indicative of a desire to reduce their resource investment into this development. During the initial stages of the development process, Alpha became aware that C2 was receiving the product, then processing the product further to make product Z, prior to selling to an end user. Furthermore, the end user had been experiencing several technical issues associated with products X and Y that were resulting in rework and reprocessing. This presented several opportunities to Alpha. Firstly, Alpha was able to develop a process innovation in which all the processing required to manufacture product Z was completed by Alpha. Secondly, Alpha was able to incrementally improve X and Y using its existing knowledge base of similar technologies (i.e., introducing new raw materials into X and Y to improve the quality and reliability of Z). Finally, Alpha were able to exploit their buying power by consolidating the purchase of the raw materials in X, Y, and Z, with existing purchases and achieve economies of scale, resulting in a 7% cost reduction.

The duration of NPD Three was approximately 4 months (ref. Table 4) and consisted of 16 iterations (ca 15%) resulting in behaviour modification prior to reaching the threshold of product development. A total of 14 iterations consisted of knowledge transfer that was highly tacit in nature. This greater access to knowledge with higher levels of tacitness compared with NPD One and NPD Two may reflect the nature of the inter-organisational relationships. For example, Alpha and Gamma had compatible knowledge bases owing to a shared experience of manufacturing products that were similar, albeit with key differences in raw materials and processing equipment, and this enabled a more efficient socialisation process. Furthermore, the incentive for C2 (and Gamma) to work with Alpha was high though it should be noted that C2 and Alpha entered into a non-disclosure agreement at the beginning of the product development to reduce the risk of C2's technologies being leaked to its competitors.

During this development, the issuing of the formulations for products X and Y by Gamma provided Alpha with knowledge of raw materials and processing methods that they had previously been unexposed to. It was viewed that due to the organisations experience of manufacturing similar products, the transfer of knowledge was relatively straightforward due to shared experiences, despite key differences in the raw materials and processing equipment. However, Alpha had to learn to adapt the formulations to work with their machinery and processing methods through the process of internalization. We posit the reward was high for both Alpha and C2, due to Gamma having lost interest in manufacturing X and Y. Consequently, Alpha was able to build on the provisioned

knowledge through a combination with existing knowledge, to provide an end product that was higher quality and lower cost.

Following is a cross-case comparison of each NPD process including a breakdown of the quantity of process steps, external inputs and behaviour modifications that were captured during the research process to illustrate sources of similarity and difference. To develop our understanding of how OI can address strategic drift and aid organisations to reach capability thresholds for innovation and change, the following section will interpret these results from the perspective of a capability proximity, whilst considering any factors that impacted external knowledge access.

Table 4 – Breakdown of NPD Processes, Steps, External Inputs and Behaviour Modifications

	NPD One	NPD Two	NPD Three
Development Process			
Duration (Months)	14	14	4
Steps	209	79	104
Iterations	43	12	16
External Inputs			
Technical or Practical	27	8	11
Tangible or Physical	-	1	1
Costing or Projections	13	1	5
Supply	3	-	1
Other	-	3	2
Total External Inputs	43	13	20
Behaviour Modifications			
Incremental Modification	34	6	7

Radical Modification	2	-	2
Thinking or Information Gathering	8	3	2
Total Behaviour Modifications	44	9	11
Mean Knowledge Complexity	31.7	38.42	8.13
Mean Significance	1.93	2.75	2.31

Comparing NPD processes from the perspective of complexity proximity

NPD One revealed a technological gap that manifested as a loss of business due to an inferior product offering in comparison to a competitor. The project leader revealed that during the NPD process there has been a preference for accessing knowledge and technical literature through websites to gather information as opposed to engaging in tacit knowledge access. This was a result of the perceived costliness of arranging face to face meetings with suppliers that were required to facilitate access to tacit knowledge, indicating resource expenditure as a factor impacting external knowledge access. It was also revealed that the focal firm were concerned about revealing their plans to suppliers to safeguard their ideas from other external actors (e.g., competitors). Thus, indicating perceived risk as a factor that impacts the propensity for an internal actor to seek external knowledge. However, the prospect of winning back the customer was the ultimate driving force behind the NPD.

After 60 failed attempts at product development, the focal firm resorted to engagements *"with [Supplier A] and [Supplier B] about the [raw materials]"*, who then sought *"further recommendations from their laboratories"*. It was reported by the project leader that had the focal firm not combined knowledge from different suppliers, a resolution to the technical obstacles would not have been found. Consequently, NPD One required a relatively greater resource investment due to opening multiple dialogues with suppliers. Furthermore, the involvement of multiple suppliers increased the risk of project information getting into the wrong hands, in comparison to gathering literature from a website or brochure or accessing knowledge from a single supplier. However, the

consequence of involving multiple actors is a greater breadth of tacit knowledge, resulting in greater possible linkages with the internal knowledge base, thus, increasing the likelihood of finding a resolution to a more complex iteration. In total, NPD One consisted of 44 behaviour modifications that were a consequence of external input, indicating a relatively distant capability proximity.

NPD Two revealed a technological gap that manifested as an opportunity to complement existing products in the firm with a new lower cost product that had very specific application properties. This would enable the focal firm to gain business by providing their customers with a new product. During the development process, there was a prominent market pull that became evident from the level of involvement from different customers who had been informed about the development and were also interested in the product. The project leader confirmed a natural tendency to seek information from websites *"as a first port of call"* due to the consideration of time investment required to obtain the necessary information. To explain this further, this was due to the likelihood of being put into contact with a non-technical supplier representative and being unable to quickly gain access to the relevant knowledge. In this instance, the project leader resorted to contacting a supplier who was able to identify a suitable component that would provide the desired properties. This was a consequence of a common understanding that had been previously developed *"off the back of the use of an existing product with similar technical properties"*. During the later stages of this project, it was necessary to engage with a customer to develop highly specific process properties. The customer had been willing to work with Alpha during development because of a mutual interest in the product. In total, NPD Two consisted of 9 behaviour modifications due to external input, indicating a relatively moderate capability proximity.

NPD Three revealed a technological gap that manifested as an opportunity to complement existing products in the focal firm through the development of a product that resolved technical issues for the prospective customer, while being manufacturable on machinery and equipment utilised by the focal firm. The development consisted of 20 external inputs that were all tacit in nature. We posit this was due to the low risk and high reward associated with customer engagements, and the focal firm's prior experience of developing similar products. Interestingly, this development resulted in unexpected cost savings of 7% due to economies of scale, and further cost savings from improved process efficiency. In total, NPD Three consisted of 11 behaviour modifications due to external input indicating a relatively moderate capability proximity.

Table 5 illustrates the perceived capability proximity developed from the analysis of the three NPD projects. Furthermore, we suggest conceptual terms that refer to the factors that influenced the engagements as resource investment, perceived risk, and reward.

Table 5 - Perceived Capability Proximity

	NPD One	**NPD Two**	**NPD Three**
Newness to Firm	Substituting	Complementing	Complementing
Newness to Market	Competing	Competing	Competing
Development Type	Radical	Incremental	Incremental
Capability Proximity	Very Far	Medium	Medium

Towards a framework of open innovation capability thresholds

We set out to explore how OI could serve as an effective means by which firms can reduce their capability gaps and reach the necessary threshold of NPD. We have illustrated that the restoration of a firm's capability proximity with the environment is achieved as an iterative process of variably complex sources of knowledge seeking from external sources. As unknowingly described by one of the project leaders:

"Unfortunately, we don't possess a crystal ball, so we can never accurately predict how a project will pan out at the start. We tend to learn as we go, and that can be from a need to learn as we did not have the knowledge to begin with, or because we gain information from the customer as the project evolves."

The results from our analysis of three NPD projects reveals several intriguing insights during the restoration process. First, Alpha utilised OI practices by engaging with external actors during NPD

projects, to facilitate access to information that was not available within the organisation. Without this information, it would not have been possible to reach the capability threshold and consequently restore the capability proximity. Second, the firm's absorptive capacity plays an influential role in being able to recognise assimilate and exploit external knowledge (Zobel, 2017). Our analysis of these NPD projects revealed only a minority of the total activities in each development were highly influential or critical to the success of the NPD. Thus, highlighting the difficulty in not only recognising the value of external knowledge, but the process of searching for the right information. Third, the ability to access external knowledge can affect the efficiency of the NPD process. Access to knowledge can vary from being openly accessible, subscription access, explicit in nature or tacit in nature.

Furthermore, our analysis suggests access to tacit knowledge is mediated by the perceived level of resource expenditure associated with an external engagement. It might be more attractive to seek more accessible forms of knowledge due to the lower costs associated with the conveyance of that knowledge. However, overall, more difficult to access forms of knowledge appeared to provide more critical and influential input into the NPD's. Resource expenditure was also a factor for external actors, who revealed the use of techniques including ranking projects according to the probability of commercial and technical success, and the use of net present value to prioritise technical projects to manage resource investment. When describing the impact of resource investment on the propensity to engage in NPD interactions, one supplier reported:

"We are constantly reviewing the amount of time and money spent by sales and technical against the sales revenue generated, especially where new product launches are involved" in addition to, "we are also looking at how an individual customer's sales are developing and how many growth opportunities and projects we have running with them"

The perception of risk and reward also played an influential role in moderating access to external knowledge with high levels of tacitness. From the standpoint of the project leader, it was noted:

"I think about the risk when communicating with external parties, I am very protective of our formulations and intellectual properties"

Furthermore, from the standpoint of an external actor engaged in the process, one supplier stated:

"if a project contains a new product or information that is particularly sensitive, then we would just ask the customer to sign a non-disclosure agreement"

Finally, the prospective reward from engaging with an external party had an influential effect on the resource allocation that the project leader was willing to commit to the interaction:

"I would allocate more resource, if required, if I feel the project can lead to larger volume or value sales."

Considering reward from the standpoint of the external actor, it was revealed that gathering information to support the supplier's own product innovations was a perceived reward for engaging in OI practices:

"all technical and commercial information gathered from the market supports development of additive solutions for current and future needs."

Ironically, another supplier revealed the benefits of failing to succeed in providing a solution for a customer:

"we often learn more when a product fails, we can then make modifications to the existing product or develop an alternative"

Discussion

Innovation failures preceding OI activities can surface causal ambiguity in existing resources. However, while incidents like this are necessary, they do not suffice for sparking innovation. Instead, when organisational actors identify the unexpressed or poorly understood links between

resources and performance, they are better equipped to target their OI activities toward variably complex sources of knowledge to bridge the identified capability gaps. Hence, when a product fails this may or may not be an important signal indicating the emergence of a capability gap and potential strategic drift. To better judge the scale and scope of a capability gap, firms cannot act myopically by limiting their search efforts and attention near the problem domain, which is often restricted to the firm boundaries (Levinthal & March, 1993). Our findings show that under such circumstances, organisational actors can effectively resort to external sources by opening up their boundaries for OI activities during the process of NPD. These activities can facilitate novel insights, information and knowledge in order to transcend its firm specific social and historical trajectory of capability development. Our three NDP cases show that when this happens, organisations are more apt to closing the capability gap.

During the process of NPD, we found tacit knowledge provided more significant contributions to an NPD project that was more radical in nature. This may be a consequence of the difficulties associated with gaining access to, and the conveyance of tacit knowledge across boundaries as a consequence of information heterogeneity. Our research revealed the focal firm had combined tacit knowledge from multiple external sources as a means to find a resolution to a complex or difficult stage of an NPD. This supports research by Argote and Mirion-Spektor (2011) who found that increasing the number of search paths during the process of innovation can assist creativity. However, accessing information from multiple sources increases the complexity of semantic boundaries that must be overcome to facilitate knowledge transfer (Carlile, 2004). The knowledge conversion process helps to shed light on the transfer and application of these different types of knowledge (Nonaka and Krogh, 2009). Throughout our research, we observed instances of all types of knowledge conversions described in the SECI model (Nonaka and Krogh, 2009) during the process of OI. To assist externalization, the focal firm used tangible examples during face-to-face meetings to support the conveyance of issues that could not otherwise be communicated using more explicit mechanisms. We observed the process of internalization when the focal firm adopted external technologies to establish how the products could be developed to work with specific assets and machinery. In this instance, the knowledge transfer process was assisted by taking measures to reduce the level of risk in engaging with external actors, facilitating access to tacit knowledge. Moreover, during NPD One, socialization appeared to assist internalization as a secondary choice of knowledge conversion activity due to factors including resource expenditure (i.e., the costliness of accessing tacit knowledge), risk and reward. Thus, we build on research by Carlile (2004) by

revealing factors that can reduce and increase the likelihood of knowledge transfer across boundaries.

When viewed from the context of firm specific resources, the RBV argues that imperfectly imitable resources can be a consequence of social complexity and the unique path the firm has taken in history (Barney et al., 1991). Therefore, through the process of OI, an organisation with a relatively diverse product portfolio may have an opportunity to develop a relatively high number of relationships with external actors (e.g., suppliers or customers), offering the potential to leverage those resources through the process of OI to gain a competitive advantage. However, finding methods to successfully overcome boundaries to the access and transfer of external knowledge is necessary to supporting the development of new capabilities. The prospect of a reward consisting of increased trade could stoke a sense of reciprocity, increasing the motivation of external actors (Boudreau and Lakhani, 2009). Further, to increase the chances of success during collaborations with external actors, firms should focus on building trust (Flemming and Waguespack, 2007; Lee et al., 2010) and the development of soft skills.

Existing research on the RBV and dynamic capabilities is yet to reveal the origins of firm-level heterogeneity and the sources of enterprise-level value creation (Teece et al., 2014). To develop a greater understanding of this enigma, our research has provided a study into the deployment of dynamic capabilities in practise that have been sought in the literature (Ambrosini and Bowman, 2009). The ambition to develop new products as a means to restore a focal firm's capability proximity with the environment results in the founding of a new capability. However, it is unclear at the founding stage of capability development which combinations and types of knowledge are required to determine the set of activities necessary to reach the capability threshold. This can manifest as a process of trial and error enacted by the combination and recombination of knowledge drawn from the focal firm’s knowledge stock, which can be a laborious and resource intensive activity (Kogut and Zander, 1996). Our research contributes to the dynamic capabilities framework by firmly establishing the process of NPD as a second-order dynamic capability that is guided by the higher-order sensing process of the dynamic capability framework. Further, we posit the sensing process is underpinned by the recognition function of AC (Zobel, 2017), that works in unity with OI to provide external knowledge sources that can be harnessed during the process of NPD. Through the application of OI practices, it becomes possible to access a vast range of external knowledge that can assist the process of NPD through the provision of external technological resources. This has the potential to contribute to a firm's dynamic capabilities by increasing the number of search

paths and potential new combinations of knowledge enhancing the creativity of innovations (Argote and Mirion-Spektor, 2011), further cementing the success of NPD through increased quality, quantity and diversity of resources (Ambrosini and Bowman, 2009).

Conclusions

This research set out to answer the question of how OI contributes to the firm's dynamic capabilities and can help bridging a firm's capability gap. Through the application of an embedded multiple case approach examining the NPD process in a UK SME, we were able to reveal how knowledge from outside the firm boundary can be applied to restore a focal firm's capability proximity with its environment. We observed the SECI process of knowledge conversion during OI engagements. In addition, tacit knowledge significantly contributed to NPD projects and can be combined from different sources to overcome complex activities during the process. However, the types of knowledge sought during the NPD project, and the likelihood of gaining access to knowledge was found to be influenced both internally and externally by factors including the resource expenditure, risk, and reward associated with engagements. In conclusion, further research should investigate the influence of information heterogeneity on the success of NPD and seek to further our understanding of knowledge access during the process of OI. In addition, an opportunity exists to investigate the impact of the availability of external resources on OI activities and consequently, the firm's dynamic capabilities, whilst considering social mechanisms that have the potential to influence OI (Flemming and Waguespack, 2007; Boudreau and Lakhani, 2009; Gambardella and Panico, 2014). This will contribute to the literature on open innovation and dynamic capabilities by providing a greater understanding of how focal firm's can become more proficient in restoring the capability proximity with its environment during the process of NPD.

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Appendices

NPD One - Knowledge Complexity and Significance Scores

Iteration	Knowledge Access	Significance
1	50	2
2	10	3
3	10	2
4	10	3
5	20	2
6	50	1
7	20	2
8	20	2
9	20	1
10	50	1
11	1	5
12	15	3
13	10	2
14	50	3
15	50	1
16	1	3
17	50	1
18	50	4
19	20	1
20	15	1
21	15	1
22	50	1
23	50	1
24	50	1
25	50	1
26	50	1

27	50	1
28	15	1
29	50	1
30	1	5
31	20	3
32	50	1
33	10	3
34	50	3
35	50	1
36	20	1
37	50	1
38	50	3
39	50	3
40	10	4
41	25	1
42	50	1
43	25	1

NPD Two - Knowledge Complexity and Significance Scores

Iteration	Knowledge Complexity	Significance
1	100	3
2	30	1
3	100	4
4	10	4
5	30	5
6	10	1
7	100	1
8	1	1
9	50	4
10	10	1
11	10	3
12	10	5

NPD Three - Knowledge Complexity and Significance Scores

Iteration	Knowledge Complexity	Significance
1	10	2
2	10	2
3	15	3
4	10	4

5	10	3
6	10	3
7	10	3
8	5	3
9	5	3
10	5	1
11	5	1
12	15	3
13	5	1
14	5	3
15	5	1
16	5	1