How does Open Innovation contribute to the firm's Dynamic Capabilities?

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Abstract

A pressing management issue exists to understand how firms can develop dynamic capabilities (DC) through processes such as open innovation (OI). Our study aims to expand knowledge in this area by explicating the underlying mechanisms of OI that contribute to a firm's DC. Adopting a microfoundations perspective, we examined three separate new product development projects in a UK manufacturer over a period of two years. Our findings demonstrate that manufacturing firms can exploit technological and market-based knowledge resources during OI activities and we have developed a process model to reflect these findings. We were able to identify three underlying mechanisms of OI: realization, engagement, and appropriation, that contribute to the creation of firm resources and the firm's DC. Our study reveals that each mechanism links the process of OI to a firm's DC by sequentially and reciprocally altering the firm's abilities for sensing and seizing opportunities. This improved understanding of the microfoundations of OI enables us to explain how external knowledge search and the ensuing knowledge appropriation can correct misalignment between a firm's current capabilities and its future market opportunities, and, thus, enhance the firm's DC.

Introduction

Firms endowed with dynamic capabilities (DC) can quickly and purposefully modify and renew their resources to capitalise on market opportunities and secure competitive advantage (Teece et al., 1997; Teece, 2007). These firms develop sensing and seizing abilities that enable them to anticipate new market opportunities and then mobilize resources in response to these opportunities (Teece, 2014). Both the sensing and seizing of these opportunities is supported by external search activities that occur during the process of new product development (Teece, 2007) since these search activities yield exploitable knowledge resources located in the supplier and customer knowledge domains. At the same time,

exploiting knowledge resources from interrelated actors within the firm's external network to supplement internal innovation is seen as an important consequence of open innovation (OI) activities (Weber and Heidenreich, 2018). One conclusion that can be drawn from this apparent link is that OI is an effective route to enhancing a firm's DC (Ahn et al., 2018). Certainly, firms that successfully engage in OI are able to continue their pursuit of profits by targeting new markets with the ensuing innovation outputs (Chesbrough, 2003). Owing to its influential impact on innovation success (Chesbrough, 2003; Laursen and Salter, 2006), OI has emerged as an important topic in the innovation literature (Dahlander et al., 2021).

DC enable firms to cope with increasingly competitive dynamics and enhance performance (Vanhaverbeke and Cloodt, 2014; Teece, 2014) but, to develop these capabilities, firms need a comprehensive understanding of the underlying mechanisms or microfoundations that precede their development. Research into the microfoundations of OI is providing an emerging body of literature (Bogers et al., 2018) that can help to shed light on lower-level mechanisms that result in firm-level capabilities (Lewin et al., 2011). For example, studies have examined the relationship between openness and new idea creation (Salter et al., 2014), and the organisational mechanisms that contribute to a crowdsourcing capability (Pollok et al., 2019). Our study aims to expand knowledge in this area by explicating the underlying mechanisms of OI that contribute to a firm's DC in order to answer the question: *"How do open innovation activities contribute to a firm's dynamic capabilities by supporting the creation of firm resources?"*

Our research adopts a microfoundations perspective (Felin et al., 2015) by examining how lower-level mechanisms of the OI process influence organisational outcomes through the creation of firm resources and capabilities. Adopting this perspective has the potential to improve our understanding of how OI can enhance firm-level performance (Vanhaverbeke et al., 2014). The underlying mechanisms of the OI process that contribute to a firm's DC were

investigated using an embedded case study design featuring three separate cases of new product development (NPD) projects that took place within the firm over a period of two years that had led to the creation of new capabilities via OI activities.

By adopting a microfoundations perspective, we were able to empirically explicate lower-level mechanisms of OI that contributed to the firm's DC (Lewin et al., 2011). In doing so, we build upon earlier OI studies by revealing and theorising three mechanisms that link OI to DC: realization; engagement; and appropriation. Each mechanism has varying levels of interaction with each other and the sensing and seizing abilities of the DC framework. Importantly, our study reveals that OI activities lead to behaviour modifications that influence the product development process and contribute to a firm's DC. Further, building on the microfoundations approach, our study offers some initial steps towards advancing our understanding of the underlying relationships between the two concepts of OI and DC. Finally, these findings also have important implications for managers by providing them with insights into how OI practices can alter the resource base of a firm and instil behavioural changes in NPD projects.

The next section will explore the theoretical underpinnings of this study by reviewing the DC literature, prior to establishing the theoretical linkages that relate to OI practices. 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 Background

Researchers adopting the microfoundations perspective have established the importance of identifying and explicating lower-level mechanisms that drive firm-level outcomes. However, since its inception, different interpretations of microfoundations have emerged from the research. Some studies consider the role of individuals in contributing to firm-level

outcomes (e.g., Grigoriou and Rothaermel, 2014), whereas other studies consider the role of organisational processes and activities (e.g., Teece, 2007). We adopt a microfoundations perspective consistent with Felin et al. (2015) that microfoundations are a proximate cause of a phenomenon that exist at a lower-level than the phenomenon itself and are not necessarily reducible to individuals. For example, this perspective has been used to identify metaroutines as sources of organizational absorptive capacity (Lewin and Massini, 2003) and highlights their importance for identifying external knowledge, learning from partners and absorbing knowledge back into the focal organisation (Lewin et al. 2011).

The microfoundations approach is a powerful approach to understanding lower-level phenomena that affect firm performance and innovation. However, while conceptually appealing, its explanatory power remains to be empirically explored. For example, Lewin et al. (2011) offer a conceptual model of microfoundations for knowledge absorption but, thus far, empirical studies of the microfoundations for firms' OI activities, in particular those that generate organisational level DC, remain scant. Thus, adopting a microfoundations perspective is a promising way to increase understanding of the mechanisms that contribute to a firm's DC through OI.

Dynamic Capabilities

Continual adjustment of a firm's resources is both critical to survival in competitive markets with high rates of technological change (Teece, 2007) and necessary to keep abreast of incremental changes to a firm's competitive environment. A firm with developed DC is able to "purposefully create, extend, or modify its resource base" (Helfat et al., 2007: 4) in response to exogenous changes to its competitive environment. A firm's resource base is comprised of tangible, intangible and human assets, and capabilities that the firm either owns, controls, or can access on a preferential basis (Barney, 1991). In firms endowed with DC, these resources are continually adjusted "to a reliable and at least minimally satisfactory

manner" (Helfat and Winter, 2011: 1244). In other words, firms that have developed DC exhibit repeatable resource and capability creation, extension and modification. Under such circumstances, resource and capability creation does not occur by chance and, in agreement with Winter (2003) and Rothaermel and Hess (2007), we suggest that the DC construct can be disaggregated into interacting microfoundations that result in a firm-level capability. Developing our understanding of these microfoundations and how they interact will provide insight into how DC can develop to facilitate firm-level resource and capability creation and ensuing competitive advantage.

The microfoundations of DC enable firms to sense and seize opportunities through the reconfiguration of resources and capabilities. *Sensing* refers to a firm's ability to identify and assess technological opportunities arising from unmet customer needs (Teece, 2014: p332). DC research has emphasised the role of individuals in contributing to a firm's sensing ability when individuals understand customer needs and are able to recognise or develop new opportunities in response (Teece, 2007). This requires knowledge and information which is influenced by the individual's capability and social network (Helfat and Martin, 2015). However, relying on individuals to facilitate sensing can leave firms vulnerable as the locus of the capability is embedded within the individual. To strengthen their sensing ability, firms can benefit from developing organisational processes such as sensemaking and scenario planning that embed scanning and monitoring activities (Teece, 2014). These processes provide firms with opportunities to anticipate external technological advances enabling them to formulate appropriate responses and act on opportunities through the development of new products or processes. However, the role of organisational processes such as OI in contributing to a firm's DC remains unclear. This is significant, as new opportunities may also arise *during* the OI process when firms have access to knowledge resources situated outside the firm boundary. External knowledge resources provide firms with further

opportunities through the identification of customer needs or preferences (Tether, 2002), or alternatively, increased awareness of supplier-developed innovations (Teece, 2007). Firms may exploit external knowledge to focus existing resources in pursuit of new resources or capabilities.

Seizing refers to a firm's ability to mobilise resources in response to a new opportunity (Teece, 2014) and is influenced by a firm's choice of actions, investments and resource deployment (Helfat and Martin, 2015). Resource mobilization that occurs during seizing is underpinned by lower-level activities and routines that enable firms to reduce capability gaps and to implement new business models through resource and capability creation and the successful development of new products and innovations (Teece, 2019). The decisions that precede these activities are influenced by managers and guided by the individuals' capabilities, network and social ties and educational background and experience (Helfat and Martin, 2015). These decisions may result in the structuring, bundling or leveraging of new resources in support of the firm's seizing ability (Sirmon et al., 2011). The mechanisms by which new products and technologies arise include the OI process that makes use of knowledge situated outside the firm boundary. During OI processes, individuals make decisions that influence what a firm *does* with its existing knowledge resources in pursuit of new resources. However, the role of the OI process in contributing to seizing remains unclear. Therefore, we need to consider the potential for the OI process to contribute to firm resources and DC.

Open Innovation

The OI process supports a focal firm's innovation activities by means of search, adaptation and adoption of external knowledge (Chesbrough, 2003; West and Bogers, 2014) and has been defined as *"a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary*

mechanisms in line with the organization's business model" (Chesbrough and Bogers, 2014: 1). The distributed nature of a firm's OI process features the inclusion of external actors in innovation activities such as suppliers, customers, industry experts and consultants. In these contexts, external actors are valuable knowledge resources that firms can exploit to supplement internal innovation activities (West and Bogers, 2014; Weber and Heidenreich, 2018).

New product development (NPD) is an organizational process that facilitates the seeking out and application of external knowledge and is central to adaptation and renewal at the firm level (Brown and Eisenhardt, 1995). External knowledge sought during the NPD process can be classified as either market knowledge or technical knowledge (Cui and Xiao, 2019). Market knowledge refers to the expressed and latent needs of customers (Narver et al., 2004) and firms can best exploit it by closely aligning internal R&D, NPD activities and market requirements (Teece, 2018). Alternatively, technical knowledge is knowledge of supplied components, materials, or products that influence the features, feasibility and application of a product (Laursen and Salter, 2006). The NPD process assimilates both market and technical knowledge (Danneels and Kleinschmidt, 2001), since the former sets the direction of the NPD, while the latter supports the actual development process.

How does OI contribute to Sensing?

Existing OI research has identified firm-level mechanisms that may have implications for a firm's sensing ability. When firms engage in the OI process, search activities enable firm to draw on knowledge and ideas from external sources (Laursen and Salter, 2006). These knowledge resources may be mobilised through inbound, outbound or coupled knowledge flows (Stanko et al., 2017). Our research is concerned with inbound knowledge flows that convey external knowledge resources to innovating firms both prior to and during NPD

activities. In these contexts, search activities can provide firms with knowledge of customer needs and preferences (Laursen and Salter, 2006) and technological advances (Cousins et al., 2011). Firms may develop an astute awareness of environmental changes that over time generates DC (Helfat and Peteraf, 2003), putting them in a better position to sense new opportunities and threats (Danneels, 2011). To make best use of technical knowledge, firms must have developed capabilities to facilitate knowledge transfer (Naqshbandi and Jasimuddin, 2018). Such capabilities may be underpinned by structural, cultural or technical factors (Jasimuddin and Naqshbandi, 2019) and enhance a firm's ability to seek out and integrate external knowledge (Cohen and Levinthal, 1990). Moreover, firms that have access to a greater number of external knowledge sources can enhance incremental innovation performance (Garriga et al., 2013) and help developing new business models (Demir and Angwin, 2021). Consequently, inbound knowledge flows associated with the OI process may reduce a firm's proximity to external knowledge sources, placing firms in a better position to sense new opportunities.

Research into the OI microfoundations can be broadly classified into individual-level or project-level studies. At the individual-level, studies have established that individuals may have implications for a firm's sensing ability, as they play a role in contributing to the identification of new opportunities. When individuals are open to external sources, they are exposed to knowledge variety and may become more alert to external information (Salter et al., 2015). Consequently, these individuals become more aware of environmental changes and are better positioned to identify new opportunities that firms can exploit to develop new resources and capabilities. Research at the project-level has examined the links between knowledge search and NPD project success (Salge et al., 2013) and identified different search mechanisms that can be adopted by firms depending on the type of OI project (Lopez-Vega et al., 2016). Overall, microfoundations research has uncovered various endogenous

mechanisms that may contribute to a firm-level sensing ability. Thus, adopting a microfoundations lens is a promising way of increasing our understanding of how a firm can leverage OI to enhance its sensing ability.

How does OI contribute to Seizing?

Seizing opportunities in the marketplace, is an essential function of DC. Once a firm has identified a new opportunity, it can contribute to resource and capability creation (Helfat and Peteraf, 2003) by leveraging knowledge resources in support of developing new products or innovations (Teece, 2007). Firms that supplement their innovation activities with external knowledge resources have been found to experience higher levels of innovation performance (Laursen and Salter, 2006; Leiponen and Helfat, 2010; Weber and Heidenreich, 2018). However, these firms must also develop capabilities to integrate external knowledge with their internal organisational processes (Cohen and Levinthal, 1990; Lane et al., 2006). Thus, implicating endogenous factors such as NPD in facilitating resource and capability creation when firms mobilize resources in response to new opportunities.

During NPD, a firm may turn to OI to exploit external knowledge resources in support of resource and capability creation. Once technological opportunities have been identified, individuals that engage in the NPD process develop new knowledge by drawing on prior learning, experience and their social networks (Grigoriou and Rothaermel, 2014). Overall, we suggest firms may leverage OI during NPD in support of new resource and capability creation. However, researchers are unclear about the mechanisms of OI that contribute to new resource and capability creation.

Research on OI microfoundations has, however, identified both individual-level and project-level factors affecting a firm's seizing ability. At the individual-level, Dahlander et al. (2016) found that when individuals build relationships with external actors, they are better

able to absorb external ideas and develop new knowledge. Bogers et al. (2018) found that individuals' educational diversity had a positive relationship with their ability to access external knowledge. Yet others have found that during OI, individual R&D technicians' creativity and problem solving is enhanced when they operate in informal roles, which enables risk taking, experimentation and learning (Pollock et al., 2019). At the project-level, Du et al., (2014) found that adopting formal or informal project management approaches can impact the performance of OI projects, depending on whether external actors are science-based or market-based. Overall, these earlier studies suggest that mechanisms at a lower-level than the firm may impact a firm-level seizing ability. Although Teece (2016) has suggested firms may leverage OI in support of a seizing ability, the mechanisms of the OI process that contribute to a firm's seizing ability remains unclear. These prior studies have established the importance of OI for seizing opportunities in the marketplace. However, while prior studies have established some important *relationships* between OI and seizing—an essential function of DC—they have not explicated the microfoundational *mechanisms* by which OI contributes to new resource and capability creation.

Linking OI and DC Theory

Although existing literature has associated OI with the firm's DC (Teece, 2016; Randhawa et al., 2016; Ahn et al., 2018), there is still a lack of consensus regarding *how* DC are developed, which is a critical concern to firms wishing to create a competitive advantage. While the microfoundations literature has addressed individual-level and project-level aspects of OI, theoretical insight into the process-level mechanisms by which OI can contribute to a firm's DC has not yet been extensively developed. Indeed, Ambrosini and Bowman (2009: p44) suggest that *"it must be feasible to identify discrete processes inside the firm that can be unambiguously causally linked to resource creation"*. Consequently, integrating OI research

with that of the DC framework (Chesbrough, 2014: 3) provides an opportunity to explain how process-level activities may result in resource and capability creation. Within the OI domain, the NPD process focuses on activities that require competence in extracting market and technological knowledge (Danneels, 2016). Consequently, our study will focus on the microfoundations of OI through careful examination of the NPD process to identify OI process-level mechanisms that contribute to the development of a firm's DC.

Methodology

Research Design

Given the paucity in research on how OI can contribute to a firm's DC, we adopted a process-level outlook (Randhawa et al., 2016) by conducting an embedded case study approach of how OI activities help generating knowledge-based resources that contribute to new capabilities. This is an appropriate approach because it offered an in-depth inquiry into a specific and complex phenomenon (Eisenhardt, 2021), set within its real-world context, and yet allowing replication where each case can serve to confirm and disconfirm inferences drawn from the other (Eisenhardt, 1989). Our embedded case study consisted of three separate NPD projects using OI activities over a period of two years and had resulted in the development of new capabilities. Drawing on embedded units of analysis typically generates more robust and generalisable findings than single cases (Yin, 2018). This progressive approach enabled the identification of links between process-level activities that took place within the organisation over time and phenomena at the firm-level by adopting an outcome-driven narrative (Kouamé and Langley, 2018). This approach enabled us to track closely the actions performed by organisational actors across several functions and hierarchical levels and engaged external actors in the focal firm's innovation activities in pursuit of developing new capabilities. Hence, using multiple NPD cases not only helped us finding strong patterns

of OI enabled resource alteration patterns, but also establishing some of the building blocks for building theory (Eisenhardt and Graebner, 2007) on the development of DC. Our level of analysis was at the process-level, which provided a detailed account of how OI activities had contributed to the development of new capabilities. Our unit of analysis was the NPD activities taking place within the observed projects, both internal and those extending beyond the organisation's boundaries.

Research Setting

Our research setting was an established UK small- and medium sized enterprise (SME) in the manufacturing sector. We selected an organisation that has over 80 years' experience developing innovative and market leading products. These products cover a wide variety of market sectors ranging from specialist toy and hobby markets to more general industrial and defence markets, with each market varying in size. Consequently, the organisation has a broad customer-base served by a national sales function focused on gaining new business by gathering information on external development opportunities and market movements. The broad customer base corresponds with a diverse supply network that is used collaboratively to support the organisation's OI activities. Consequently, most of the organisation's NPD projects consist of input from a wide range of external actors, mainly customers and suppliers but also technology experts. This setting is, therefore, an ideal context for researching OI, both in terms of the activities and the actors involved (Chesbrough and Bogers, 2014). We identified the mechanisms by which OI activities contributed to the organisation's DC through careful examination of NPD processes for a period of two years. During 2017 and 2018, the organisation completed 197 and 196 development projects respectively, with 28.6% of the projects leading to sales revenues. In 2019, 54.3% of the organisation's sales revenues were attributable to products introduced during the previous five years. The continually

evolving portfolio underpinned by successful NPD projects demonstrates continued support to the organisation's DC through OI activities.

Case Selection

We selected three NPD projects that began with varying levels of market demand for the products under development and had therefore been assigned different resource allocations. To identify relevant NPDs, we selected a cross section of projects using theoretical sampling (Eisenhardt, 1989) to meet the following criteria: 1) projects were recent; 2) had disparate driving forces; 3) included significant input from external actors; and 4) had resulted in an established and revenue generating product in the organisation's portfolio. Our criteria ensured that OI activities were performed throughout the NPD process and that the development had concluded. Thus, we ensured all the possible engagements with external actors had been captured and the projects had resulted in new capabilities.

The first NPD project had been initiated within the organisation in response to a loss of business to competitors, owing to the organisation's inferior product offerings in the market. This NPD illustrated a capability gap and competitive disadvantage concerning the organisation's offerings and its market requirements. The second and third NPD projects had arisen from external market drivers. The second NPD was in response to a requirement for a product that would enable a specific customer (i.e., an external actor) to compete in its existing markets at lower cost, providing a competitive advantage for its business. The third NPD was initiated following a new potential customer's concern that its existing supplier was using process technologies that were no longer appropriate for the product it was supplying. Both the customer and the current supplier had experienced technical and manufacturing issues, and both were seeking to exit the relationship in a satisfactory manner. This set of three cases provided contrast between the disparate forces driving innovation in the sense that it features initiation by internal forces and clear external/market forces. This is an appropriate

method for sampling multiple cases in pursuit of theory development (Eisenhardt and Graebner, 2007) as it provides insight into a variety of factors driving the need for new capability development and how this was achieved.

Data Collection

Our primary data collection was conducted by the lead author, a researcher-practitioner who was employed by the organisation in a senior technical role throughout the duration of the projects. This enabled access to project reports and all communications recorded during each product development. Furthermore, he had easy access to all the organisation's functions that participated in the developments, as well as participating in a technical evaluation and quality control role throughout the research duration. His familiarity with the organisation and its data sources and terminology enabled an unusually rich and focused approach to data collection. Both co-authors were independent of the organisation. They participated and advised during the data collection process to ensure we collected all available contemporaneous archival data relating to each product development. These data included: preliminary costing and technical requirements; project activities; project reports; and notes from any meetings held between internal staff and external actors.

We obtained all recorded communications associated with the corresponding NPDs from within the organization (Table 1). These comprised emails between internal staff revealing any attempt to gain knowledge from the existing knowledge source and emails between internal and external staff revealing any attempts to gain knowledge from an external knowledge source. Meeting minutes and reports ranged from brief summaries, to more comprehensive multiple page documents. These data enabled us to construct a data collection framework for each of the three NPDs, whereby depth could be added through subsequent qualitative data capture from available actors that had participated in the projects.

Table 1. Amount and Type Data Obtained for each NPD

DATA SOURCE		NPD One	NPD Two	NPD Three
Emails	*Pages (amount obtained/total available)*	231/231	92/92	104/104
Meeting Minutes	*Documents (amount obtained/pages)*	5/27	3/17	2/2
Reports	*Documents (amount obtained/pages)*	16/25	2/28	4/18
Informal Discussions	*Total / Duration (Hours)*	7/3.5	6/4	7/3
Semi Structured Interviews (*Internal/External Actors)*	*Total / Duration (Hours)*	2/2	3/3	3/3

Following this, we held informal meetings with all the available internal actors that had been involved in the NPDs (i.e., project leaders, developers, production and sales staff) to review and validate the data captured. All actors involved in this research were "key" (Yin, 2018) or "elite informants" (Aguinis and Solarino, 2019: 3) who were selected because they had deep knowledge of the projects (Miles and Huberman, 1994) and "extensive and exclusive information and the ability to influence important firm outcomes, either alone or jointly with others" (Aguinis and Solarino, 2019: 3). Such informants are often rare and provide crucial information that is central to the research question (Miles and Huberman, 1994). Hence, similar to Bingham and Eisenhardt (2011), we chose these informants as they were considered "innovators" and had the most insight on the entire NPD process and helped generating specific and salient data.

Next, we conducted semi-structured interviews with project leaders and any internal staff that participated in the NPDs. The interviews lasted a duration of six hours in total and each included an opportunity for an open discussion. During the interviews, participants had been asked to identify the driving forces behind all engagements of each project where external knowledge had been sought. Following these interviews, we asked participants to identify any actions arising because of the OI engagement and to score the significance of the contribution of each OI engagement to the overall project. To capture this data, developed a questionnaire using a Likert-type scale with descriptions rating from "*no influence on the success of the development*" to "*absolutely critical to the success of the development*." This discovery process revealed the factors that influenced decisions to obtain external input and, more importantly, revealed how OI inputs had influenced the NPD through knowledge flows and had resulted in new capabilities. 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 actions or behaviour during this interaction?"*. During the subsequent data analysis, we conducted a further round of semi-structured interviews with the project leaders to shed light on the key themes that were emerging from the data. The interviews lasted two hours in total. During these interviews, project leaders were asked about the extent to which new processes or routines had been deployed in future interactions with external actors. These findings were supplemented with telephone interviews with external actors who had been identified as having a substantial contribution to the NPD process. Interviews that were relevant to the research question were selectively transcribed, resulting in 27 pages of raw data. The commercial sensitivities associated with NPD Three limited our access to the external actors involved. This was compensated for during the internal interviews and discussions and

additional data was sought from notes in internal documents, meeting minutes, email exchanges and other sources.

Data Analysis

We conducted our analysis in four stages and combined case analysis (Eisenhardt and Graebner, 2007) with grounded theory procedures (Corley and Gioia, 2004) to produce a deep insight into our objects of study. Our data analysis was performed in concert with our data collection to enable the continual refinement of data capture based on emerging themes, the relevant literature and the data (Corley and Gioia, 2004).

During stage one, we established a grounding of the phenomenon being studied by developing a timeline of each NPD project using the archival data. We mapped out the number of interactions that had occurred during each project and inserted a summary of the activity that had taken place into the timeline, alongside a corresponding timestamp. Following this, we reviewed all email dialogues obtained from each project with the project leader, and manually coded these dialogues using in-vivo codes representing the actor that participated in the communication, the type of communication, and a brief summary of the communication. Similarly, we inserted this data into the corresponding NPD timeline in date order, alongside a timestamp. This provided a preliminary overview of the frequency and type of communications between actors operating internally with external actors throughout each NPD.

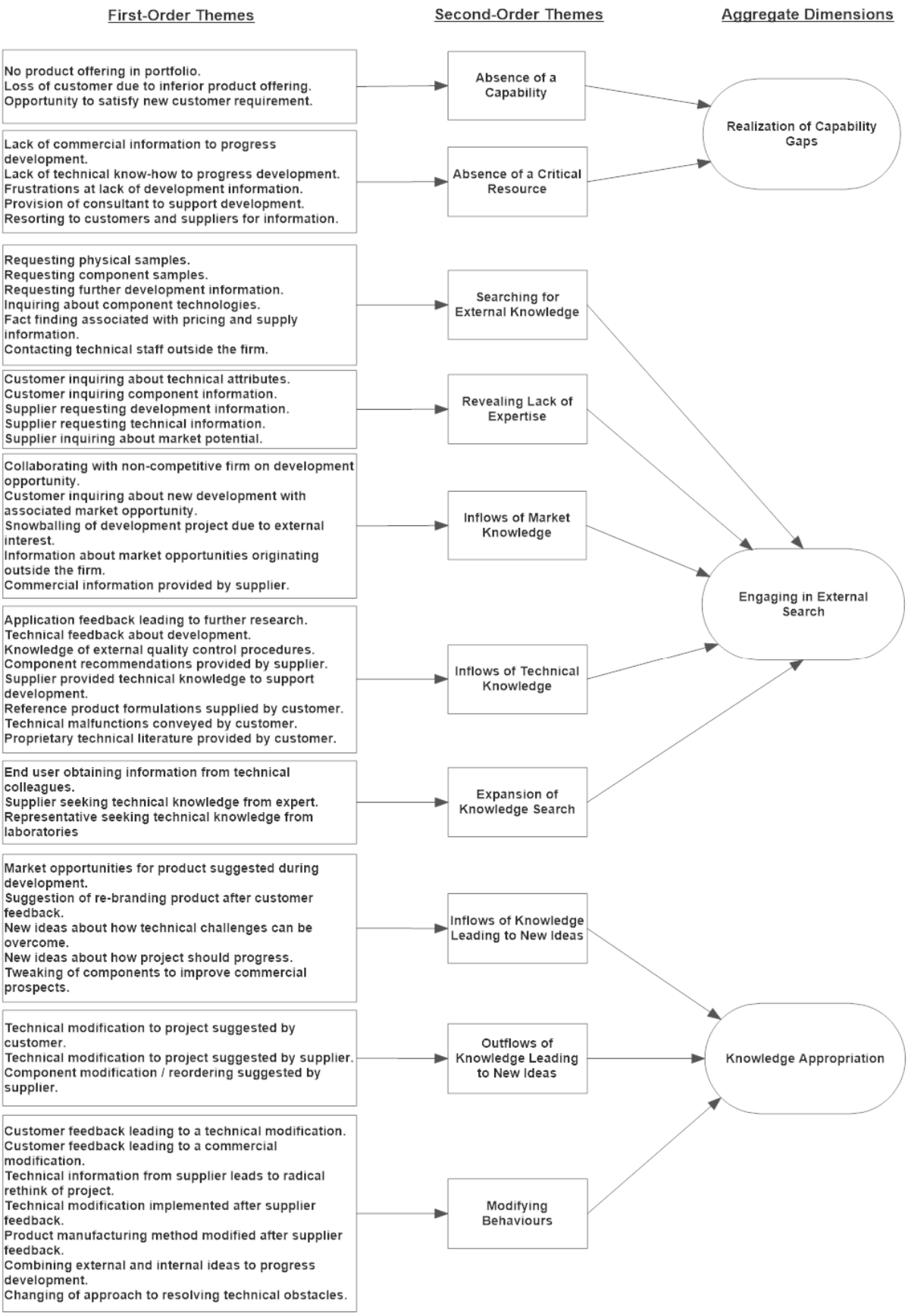
During stage two, we inserted the driving force behind all engagements with external actors into each NPD timeline. This had the effect of associating the ‘why’ behind the OI engagement with the corresponding activity and revealing what knowledge had been sought from external actors. To understand better both the nature of the engagement and how the external actors had influenced the NPD, we also inserted into the NPD timelines the resulting input and any activities associated with each step of the NPD project. Then, we inductively

generated themes concerning inputs and activities in correspondence with the project leaders that were refined iteratively during the subsequent interviews and discussions that were conducted for each NPD.

During stage three, we inserted the significance and contribution of external inputs to the completion of the overall project into the NPD timelines. We asked the project leaders during the subsequent interviews to elaborate on the reasons behind the scoring and how the activities had influenced the overall project. This helped provide a deeper understanding of why certain activities had greater significance. Importantly, it revealed comprehensively how external actors had influenced the NPD project and the firm by highlighting potentially significant capability gaps that had been bridged during the project.

During stage four, we further analysed the textual data, interview transcripts, project reports and email exchanges. This was usually completed in the sequence they were conducted, although sometimes simultaneously and in different activity sites (Demir and Lychnell, 2015) to develop an understanding of the OI activities underpinning the alteration of DC. Following Gioia et al. (2013), the analysis was accomplished in three steps by reading and rereading the data, coding events, actions and activities associated with OI until a categorical scheme was developed (see Figure 1).

Figure 1. First-Order Themes, Second-Order Themes and Aggregate Dimensions


First-Order Themes
Second-Order Themes
Aggregate Dimensions
No product offering in portfolio.
Loss of customer due to inferior product offering.
Opportunity to satisfy new customer requirement.
Absence of a Capability
Lack of commercial information to progress development.
Lack of technical know-how to progress development.
Frustrations at lack of development information.
Provision of consultant to support development.
Resorting to customers and suppliers for information.
Absence of a Critical Resource
Realization of Capability Gaps
Requesting physical samples.
Requesting component samples.
Requesting further development information.
Inquiring about component technologies.
Fact finding associated with pricing and supply information.
Contacting technical staff outside the firm.
Searching for External Knowledge
Customer inquiring about technical attributes.
Customer inquiring component information.
Supplier requesting development information.
Supplier requesting technical information.
Supplier inquiring about market potential.
Revealing Lack of Expertise
Collaborating with non-competitive firm on development opportunity.
Customer inquiring about new development with associated market opportunity.
Snowballing of development project due to external interest.
Information about market opportunities originating outside the firm.
Commercial information provided by supplier.
Inflows of Market Knowledge
Engaging in External Search
Application feedback leading to further research.
Technical feedback about development.
Knowledge of external quality control procedures.
Component recommendations provided by supplier.
Supplier provided technical knowledge to support development.
Reference product formulations supplied by customer.
Technical malfunctions conveyed by customer.
Proprietary technical literature provided by customer.
Inflows of Technical Knowledge
End user obtaining information from technical colleagues.
Supplier seeking technical knowledge from expert.
Representative seeking technical knowledge from laboratories
Expansion of Knowledge Search
Market opportunities for product suggested during development.
Suggestion of re-branding product after customer feedback.
New ideas about how technical challenges can be overcome.
New ideas about how project should progress.
Tweaking of components to improve commercial prospects.
Inflows of Knowledge Leading to New Ideas
Technical modification to project suggested by customer.
Technical modification to project suggested by supplier.
Component modification / reordering suggested by supplier.
Outflows of Knowledge Leading to New Ideas
Knowledge Appropriation
Customer feedback leading to a technical modification.
Customer feedback leading to a commercial modification.
Technical information from supplier leads to radical rethink of project.
Technical modification implemented after supplier feedback.
Product manufacturing method modified after supplier feedback.
Combining external and internal ideas to progress development.
Changing of approach to resolving technical obstacles.
Modifying Behaviours

During our analysis, we triangulated our data by continually comparing the textual data with the NPD timeline and revisiting the actors involved to resolve any inconsistencies. In the first round of this analysis, we stayed close to our data, coding terms used by our informants and in documents into first-order concepts. Then, we revisited the first-order concepts and assessed whether they had captured enough detail and could serve as plausible accounts of OI activities. This step further involved matching and grouping concepts based on their similarity and compatibility into second-order themes. Finally, we aggregated second-order themes into three analytical dimensions representing how OI contributes to the firms' DC.

Findings

We present our results in four sections. Initially, we present three higher-order concepts and their microfoundations that we distilled from our analysis of the three NPD cases. Subsequently, we consider the process-level outputs that result from the interactions between these concepts. In this section, we refer to the organisation responsible for the NPD projects as Alpha. Similarly, we reference specific external actors with pseudonyms to protect their anonymity. Following is an overview of each NPD project and the number of individual engagements that we discuss throughout this section (Table 2).

Table 2. External Inputs that Impacted Each NPD

	NPD One	**NPD Two**	**NPD Three**
Total Quantity of Individual Engagements	154	29	73
Purpose Types (Rationale Behind OI engagement)	27 Product Characteristics 5 Product Features 16 Market Potential	10 Product Characteristics 3 Product Features 3 Market Potential	7 Product Characteristics 3 Product Features 3 Feasibility of Product 2 Market Potential
External Actors Involved	11 Supplier	4 Customer 1 Supplier	5 Customer 3 Supplier

Engagement Types (Means and types of engagement)	43 Information Sharing	11 Information Sharing	14 Information Sharing
Resulting Inputs	27 Technical 13 Component Costing 3 Supply	8 Technical 1 Component Costing 3 New Collaboration Opportunity 1 Physical Sample	11 Technical 5 Component Costing 2 New Collaboration Opportunity 1 Physical Sample 1 Supply
Behaviour Modification	28 Changes of base component. 5 Changes of component ratios. 1 Modification to Component Ordering 2 Changes to Internal Actors Thinking 2 Fundamental Product Changes 6 Attempts to gather more Information	4 Change of Component 2 Modification to component order 2 Change to Internal Actors Thinking 1 Information Gathering	3 Change of Component 1 Modification to Component Order 2 Information Gathering 2 Modification to Manufacturing Process 1 Fundamental Product Change 2 Change to Product Specifications

Realization of Capability Gaps

At Alpha, NPDs are normally initiated in response to a market opportunity, either identified internally or prompted by an external actor. The initiation of NPDs inevitably revealed a knowledge gap in the firm rather than knowledge availability. Conceptually, the *realization of capability gaps* preceded resource or capability creation and is underpinned by the initial recognition of an *absence of a capability,* followed by a condition where the focal firm had *an absence of a critical resource* required to develop the product (Table 3).

Table 3. Realization of Capability Gaps – Conceptual Descriptions and Empirical Examples

Second Order Theme	Conceptual Description	Empirical Example

Absence of a Capability	When an innovating firm recognises a market opportunity that has the potential to support growth of the focal firm.	"he's not got anything to go up against this [competitors] product, and he can't get in there on price" "they travelled to [customer] where they were told [customer] would not be renewing the [product] contract in favour of [competitor] citing a loss of gloss as the main reason for the move" "[beta] contacted us with an opportunity to supply these two [products] they were making for [gamma]"
Absence of a Critical Resource	Represents a lack of knowledge within the focal firm required to develop a new product.	"This leaves me in a difficult situation, because I feel like I've exhausted all the 'tricks of the trade' with the current [components]. I know there is something not quite right… please let me know your thoughts" "We were utilising [consultant] on this project due to his contacts and knowledge of the [component] industry." "We have manufactured somewhere in the region of 60 [products] and not achieved a product we deem suitable for end use"

Absence of a Capability

In all three developments, the recognition of a capability gap was the driving force behind establishing the requirement for a new capability. This manifested itself as the lack of a product offering to satisfy a market requirement and, in each instance, the awareness of such a gap originated from an external knowledge source. During NPD One, Alpha had been called to visit a key customer (C1) who were regularly purchasing one of Alpha's established products. During the meeting, Alpha were informed that C1 *"would not be renewing the [product] contract in favour of a [competitor]" (Director).* This was a consequence of long-standing technological problems and the associated *"lower quality finish of the end product." (Project report).* To have a chance of gaining back the lost business, Alpha would need to develop a product that was technically comparable to the competitor's but surpassed it in quality.

NPD Two was initiated after one of Alpha's representatives paid a cold call visit to a prospective customer. The visit was motivated by Alpha targeting increased sales in a familiar market. During the visit, the customer made the representative aware of a competitor's product that they were using in substantial volumes. However, at this time, Alpha did not have a comparable substitute: *"he's [representative] not got anything to go up against this [competitors] product and he can't get in there on price" (Project Leader).* Unfortunately, Alpha's nearest substitute was too expensive to be a viable option. At this stage, Alpha recognised the requirement for a new, more competitive product.

NPD Three was initiated when a collaborating firm's (Beta) Managing Director established contact with Alpha's Laboratory Manager to query the possibility of toll manufacturing a product for Beta's customer (Gamma). Both Beta and Gamma were trading in a market that was unfamiliar to Alpha. However, the product shared similarities with an existing product in Alpha's portfolio that Alpha manufactured using different equipment. At this stage, it was not clear whether Alpha could manufacture the product with their equipment. This created a circumstance where Alpha would *"need to develop the capability to manufacture a novel product, using our equipment that would conform to [Gamma's] requirements" (Project leader).*

Absence of a Critical Resource

In these three examples, access to external knowledge led to Alpha identifying capability gaps, which subsequently led to the initiation of NPDs. During the initial stages of these NPDs, Alpha realised it lacked critical knowledge resources to progress the NPDs and began knowledge searching activities.

In NPD One, Alpha had historically failed to develop a competitive product. This was a cause of concern as Alpha *"lacked the technical ability to develop a product that could be traded" (Industrial Sales Manager)* and was seen to be falling behind competitors. Initially,

Alpha searched for knowledge on component technologies and manufacturing methods using industry leading suppliers' websites and engaged an external consultant to gain expert knowledge of one of the product's components. However, this did not provide the necessary solutions as Alpha lacked the technical knowledge and capability to progress the development: *"we have manufactured somewhere in the region of 60 [products] and not achieved a product we deem suitable for end use" (Project Developer)*. It appeared Alpha had used a trial and error approach to achieve a product with the desired properties but had been unsuccessful thus far.

In NPD Two, Alpha *"had a product that would go through [processing method]" (Project Leader)*, but Alpha was not aware how the cost of the existing product (P) could be reduced to achieve the price level required by the market. Similarly, Alpha searched supplier websites for information about component technologies that could be used. However, the information was limited to basic component families and properties, which did not provide a solution. Consequently, Alpha needed to obtain knowledge of component technologies and recommendations for reducing costs from its suppliers.

In NPD Three, Beta *"had been experiencing technical frustrations and challenges with the product that were leading to defects and a high rejection rate" (Project Leader)*. Initially, Alpha's development team were unsure how, or even whether, Alpha could manufacture the products on its equipment despite its familiarity with the component technologies. At this stage, it was also unclear whether Alpha could resolve the technical issues Gamma was experiencing. Consequently, Alpha required information about the existing manufacturing equipment, product formulations and defects, and quality control specifications and procedures.

While all three NPD projects were not similar in size and scope, they all lacked the requisite knowledge resources to progress the development.

Engaging in External Search

As Alpha's knowledge gaps were exposed and demonstrated their lack of capability in pursuing the NPDs, they began engaging in external search to bridge these knowledge gaps. As illustrated in Table 2, NPD One involved the largest amount of external engagements (154 occasions), which is indicative of its large knowledge gap relative the other NPDs. This project was also the most complex, involving at least eleven external actors. Engaging in external search (Table 4) was underpinned by five lower-level mechanisms: *searching for external knowledge*; *revealing a lack of expertise; inflows of market knowledge; inflows of technical knowledge;* and *expansion of knowledge search*.

Table 4. Engaging in External Search – Conceptual Descriptions and Empirical Examples

Second Order Theme	Conceptual Description	Empirical Example
Searching for external knowledge	Searching for knowledge outside the firm to support new product development.	"I asked for some wet samples off the customer because I wanted something to look at. We also got some of the [component]." "There was a requirement to get some external input in i.e., from supplier in terms of what have you got that is going to enable us to do this." "Hi [Supplier], this is a bit of a long shot, but are you aware of any [components] that are good for stabilizing [component] in [product type] systems?" "We visited some development chemists at [supplier] and are working closely with them to resolve these challenges."
Revealing Lack of Expertise	A customer or supplier demonstrating a lack of knowledge about the new product development.	"The customer was asking whether this product that has been developed will go through [application method]." "she was asking us whether we could go [component] free and I said yes that's an option." "The result with [component a] and [component b] is very strange, as this never usually gives any problem…. Do you what temperature the [products] are getting to?"

Inflows of market knowledge	New market opportunities presented during the development process.	"On an unrelated note we're looking for [new product type] – is this something you can offer?" "[customer] shared information on some customers that he's had that will be interested in this product" "it sort of snowballed from one customer with one colour to this is a saviour of cheap [product type]. We knew at that point there was going to be other customers involved."
Inflows of Technical Knowledge	Technical knowledge from outside the organisation being communicated to the innovating firm.	"it was the [product] feedback with the [aesthetic property] which was obviously a little set back...we've made a decision to do a bit more research if you like." "In your [product] system, I'd look to replace [component a] and [component b] with [component c] as this is a better for [components] like [component type]." "I have enclosed TDS for you to review and presentations on the influence of the [property] of [component a] on the effectiveness of [component b] and [component c]."
Expansion of Knowledge Search	Technical knowledge outside the firm being provided by an extension of the original recipient.	"I have been in touch with a company [company name], to give me some recommendations for newer, efficient [component types] to try, that have a better tox profile and I am just awaiting delivery of samples." "Please can you suggest anything for [Alpha], I was thinking [component], but also are there further questions from [development chemist] that needs answering to suggest the possible cause of the [technical issue]?" "The Auto lab commented your [component] should not be a problem to stabilise in, and recommended [various components]"

Searching for External Knowledge

In NPD One, Alpha lacked technical knowledge about interactions between component technologies, the sequencing of components and component ratios. Consequently, Alpha resorted to knowledge searching activities with suppliers where Alpha shared detailed

information about technical issues. For example, during the early stages of the NPD, Alpha provided detailed feedback to one supplier regarding difficulties stabilising the product components stating *"I would be interested in your comments and recommendations for stabilising the [product]…" (Project Leader).* However, as the project progressed and Alpha evaluated new components, further obstacles became evident: *"I'm disappointed that the [component a1] causes adhesion issues, as the [products] had zero float and were perfect in terms of rheology, cost etc. This represents a major setback for us" (Project Leader).* This resulted in a sustained level of supplier involvement despite retaining the external consultant throughout the project. Alpha contacted additional suppliers for ideas about how to overcome this issue: *"This is a bit of a long shot, but are you aware of any [component a] that are good for stabilizing [component b] in [component c]? I've tried [component a1] (this works but poor adhesion), [component a2] seems very floaty and flocculates when [component d] is added." (Project Leader).* Unfortunately, the consultant's expertise was limited to a single component, but the product consisted of multiple components that interacted with each other in diverse ways with the potential for any combination of components affecting the technical properties of the product.

In NPD Two, initially Alpha sought supplier knowledge to understand how to develop a product at a specified cost, whilst offering specific application and aesthetic properties. At this time, Alpha was not aware of how this could be achieved so it contacted a supplier to obtain knowledge of component technologies: *"You may remember we briefly spoke just before Christmas regarding an alternative to [component name], as you have a [component type] with lower hydroxyl functionality that could work for us…to get nearer as an equivalent and also drive our costs down a bit I would be interested in this [component type] for this new development. If you have any further information, I would be very interested, also we would need samples, but the important thing is that I can use the [component type] for airless*

application" (Project Leader). As the development progressed, Alpha manufactured product samples using the recommended components. However, Alpha had to obtain customer knowledge because they lacked understanding of how the novel product would perform using this component: *"they'll know (supplier) about the product because of the track record of who they've sold it in the past. We sprayed some out airlessly, but smallish panels, and we've relied on providing samples and getting feedback from the customer" (Project Leader).* Unfortunately, the feedback revealed new technical challenges concerning the aesthetic properties of the product. This led to continual customer involvement during the later stages of the project.

In NPD Three, Alpha engaged in knowledge searching activities for several reasons. At the beginning of the development, Alpha had limited knowledge of the product Beta were manufacturing for Gamma. Beta had supplied Alpha with *"rudimentary product formulations consisting of components, ratios and a processing method" (Project Leader)* but it had still been necessary for Alpha to visit Beta: *"it's not a straightforward cut and dry, here's a formula, just fit into the way you do things…I asked for retained samples because although we had the formulas, I wanted to actually look at some of the [product]."* During the visit to Beta, Alpha used the opportunity to observe its manufacturing equipment and engage with its technicians to gather further information about the development. Alpha also sought information about the product components as *"there were a few [components] that we [Alpha] weren't familiar with" (Project Leader).* As the development progressed, Alpha sought further knowledge of Gamma's QC testing procedures due to inconsistencies that led to technical issues: *"it passed the QC specs as provided, but they came up with this other thing they do called the evil cam" (Project Leader).* Throughout this development, it had been necessary for Alpha to obtain further information about technical issues Gamma was experiencing in order to make product improvements that would overcome these issues.

Revealing Lack of Expertise

Once Alpha had engaged in knowledge searching activities, it found that its suppliers lacked expertise resulting in reciprocal knowledge searching activities. In NPD One, a supplier requested information about the product under development and its associated market potential. This type of knowledge was required for the supplier to commit resources to the development: *"All technical projects are entered in project management system ranked by commercial success and technical success. Net Present Value is our preferred method for budget decisions and choosing between and prioritizing technical projects" (Supplier).* Throughout the duration of the project, suppliers requested technical feedback: *"Do you know what temperature the [products] are getting to?" (Supplier)* and further knowledge about the project. This was a strategy used by suppliers to help eliminate technical issues. During this process, it had been necessary for Alpha to support knowledge transfer with specially developed tangible graphical illustrations of the issues experienced.

In NPD Two, once Alpha engaged in knowledge searching activities, the supplier sought knowledge of the type of product being developed and whether Alpha was aiming to switch to a higher value component. The prospect of Alpha switching the component was a major cause of concern to the supplier, which manifested itself as a reluctance to share information. However, after some reassurance from Alpha, the supplier agreed to support the development: *"I will order both samples and see if [manufacturer] can give any further price support as it's additional business rather than a cannibalisation of the [component] business" (Supplier).* During this development, one customer demonstrated interest in the development and, to generate product sales, requested further information about the product: *"You were to get back to me with info on all aspects of the new [products] but not seen anything. Can you update me." (Customer).*

In NPD Three, Gamma sought information from Alpha about the component technologies used in the product formulation and technical information about component interactions and behaviours in the product: *"The TDS [technical data sheet] does offer some recommendations for using [component type], but like I say, we would look to move away from [component type] for any new developments/modifications. I'd be really happy to receive any recommendations of materials to try, if you have any" (Technician, Gamma).* This request demonstrated a lack of technical expertise to achieve the desired product modifications, despite Gamma's ownership of the formulation. During this development, Gamma also enquired about Alpha's knowledge of a specific and unrelated product type and appetite for further collaboration: *"I am looking for an [product type] for one of our new [product systems]" (Technician, Gamma).* This appeared to arise from the positive experience associated with the initial development and learning about Alpha's technological capabilities.

Inflows of Market Knowledge

Following knowledge searching activities, reciprocal inflows of market knowledge occurred in two projects. In NPD Two, a customer had appeared willing to provide market-related opportunities to Alpha: *"first and foremost the development was for [customer] and since then it has snowballed" (Project Leader).* As the project progressed, two additional customers showed interest in the product, one of which shared information about further prospects: *"(C1) shared information on some customers that he's had that will be interested in this product"*. This appeared to be a consequence of the mutual benefit gained from succeeding with the development and would later enable Alpha to target previously unknown market opportunities with the product.

During NPD Three, towards the later stages of the development project, Gamma inquired about an opportunity for collaboration on a new project: *"I was hoping we may be able to have a conference call tomorrow afternoon to discuss a new project we may have for you." (Technician, Gamma).* The initial knowledge exchanges identified a three-month timeframe and, at this time, Gamma stated *"we would be looking for stock in August (the sooner the better to be honest)" (Technician, Gamma).* The new opportunity appeared to arise due to the positive experience associated with the project timescale and technical success of the project. When Gamma conveyed the requirements for the new project, they stated, *"this is urgent, and we will need this on a quick turnaround" (Technician, Gamma).* Thus, indicating the importance of project turnaround to capitalise on the opportunity.

Inflows of Technical Knowledge

Following knowledge searching activities by Alpha, our research revealed reciprocal inflows of technical knowledge occurred. During NPD One, there were 43 instances of inflows of knowledge. The main type of knowledge inflow was technical (27), followed by cost (13) and supply (3). In general, knowledge inflows were in response to a knowledge gap that existed within Alpha, manifesting as a technical obstacle that was preventing NPD progress. For example, a supplier technician was asked *"Have you any idea how I might increase compatibility between [supplier components] and this [product system]?" (Developer)* to which they responded *"There are a few options here, have you tried adding [component] in a small amount (1.5% by weight) as the [products] are mixing in the base? This is known to help reduce [product defect]". (Supplier Technician).* After this, Alpha implemented the suppliers' recommendations which led to further questions and reciprocal knowledge inflows. Compared to the other NPDs, Alpha had the widest knowledge gap to bridge in order to complete this development: *"we have exhausted all of [suppliers] recommendations" (Project Leader).*

During NPD Two, there were 13 instances of inflows of knowledge. Most knowledge inflows were technical (8), followed by physical inputs (1) and cost inputs (1). Prior to this project, the prospective customer provided Alpha with knowledge of product requirements (e.g., aesthetics, target costing, application properties) in descriptive format, and samples of a competitor's product. Alpha's knowledge gap associated with its customer requirements led to the recommendation of a component with similar properties to one Alpha currently used, but at a lower cost: *"[component name] is a much more economical option of 2 fronts, it has a lower OH value so less isocyanate and also the buying price is lower. It is a good standard GI grade but not as high spec (more in terms of weathering) than the [existing component] – I think this would be ideal for your needs" (Supplier).* However, as the product required multiple components that had the potential to interact with each other, it was necessary to develop some physical samples in the laboratories prior to drawing on customer input to validate the product. Subsequently, the customer provided vital feedback that enabled the project leader to *"get a feel for how the product was performing" (Project Leader)*, leading to further ideas and minor adjustments to the product.

During NPD Three, there were 20 instances of inflows of knowledge. Most knowledge inflows were technical (11), followed by physical inputs (1), cost inputs (1) and supply inputs (1). At the beginning of the development, Beta supplied *"rudimentary product formulations consisting of components, ratios and a processing method" (Project Leader)*. Alpha also requested tangible samples of the existing product, in addition to a product component: *"They supplied wet samples because they were requested at the meeting, and Danny took a drum of [component] in his car and brought that into our place" (Project Leader).* During the later stages of the project, Alpha manufactured physical samples to Gamma for trials with their end user to check the feasibility of the product. Upon initially submitting the samples, several unanticipated and unrelated technical issues had occurred: *"Attached are some photos of*

glass slides we have dipped into the [product] and cured. They show some [defect], so just needed to chat to you guys about this, as we cannot send this to our customers in this form. We'll talk you through this later." (Technician, Gamma). At this stage, Alpha requested the quality checks performed by Gamma prior to releasing the product, to enable Alpha to gain a deeper understanding of the technical issues Gamma wase experiencing and how to overcome them.

Expansion of Knowledge Search

The external actors that Alpha initially contacted did not always possess the knowledge required to overcome the technical issues experienced during the NPD projects. Under such circumstances, external actors sometimes initiated an expansion of knowledge search that resulted in further inflows of knowledge. In NPD One, a supplier used this technique to request input from their satellite laboratories owing to a lack of technical knowledge relating to an issue*: "The Auto lab commented your [component] should not be a problem to stabilise in and recommended [various components]" (Sales Manager, Supplier).* Another supplier used the same technique through an upstream component supplier: *"Please can you suggest anything for [Alpha], I was thinking [component], but also are there further questions from [development chemist] that needs answering to suggest the possible cause of the [technical issue]?" (Technical Service Manager, Supplier).* In both instances, this reciprocal activity facilitated knowledge inflows from previously unknown or directly inaccessible knowledge domain. During NPD Three, Gamma contacted a component supplier to gain further technical information to make further product improvements: *"I have been in touch with a company [company name], to give me some recommendations for newer, efficient [component types] to try, that have a better tox profile and I am just awaiting delivery of samples." (Technician, email).*

Knowledge Appropriation

At Alpha, successful NPD teams demonstrated appropriation of externally sourced technical or market-related knowledge. Conceptually, *knowledge appropriation* (Table 5) consists of *inflows of knowledge leading to new ideas*, *outflows of knowledge leading to new ideas* and *modifying behaviours*. We observed these knowledge resource creating processes throughout each example.

Table 5. Knowledge Appropriation – Conceptual Descriptions and Empirical Examples

Conceptual Description	Second Order Theme	Empirical Example
Inflows of Knowledge Leading to New Ideas	External knowledge input that stimulated a new idea inside the firm to support the product development.	"The customer said it was really good and it actually it feels like a more expensive [product], so I thought, do you re-label it as something else and sell it to a different market to a different customer" "we get in the [competitor] products, and we say, aha it's actually quite a different mixing ratio, so straight away there's a limit with your [component type a] which is the other side of the equation. So, when I spoke to [supplier], I said look we need something like [component type b], it must go through [processing method], but it must have a lower [component type a] demand."
Outflows of Knowledge Leading to New Ideas	Internal knowledge output that stimulated an idea outside the firm to support the product development.	"Or adjust the order of addition? Adding some [component a] before [component b] can help to prevent issues with gelation." "I think that a polymeric 'grinding medium' could eventually be a better choice for the [component type]"
Modifying Behaviours	Internal behaviour modification following external knowledge input.	"The biggest change to the product has been from the feedback on the down glossing...what we did, we took out the [component a] because it tends to leave an oily residue and swapped it for [component b]." (after supplier recommended trying a different component) "We had a meeting with [supplier] to discuss one of their [components] that is compatible with a range of [product families] I intend to begin formulating some [products] using this [component] and hope to have a range of prototype [products] next month." "they [customer] were saying we're suffering from [defect] is there something you can do, and

> we said yeah we can look at it. When we started looking at the formula, we had a quick look and I wanted to try something. I thought we could also try a bit of [component] in the [product a] and the same [component] that's in the [product b] and see what that's like."

Inflows of Knowledge Leading to New Ideas

During NPD One, Alpha sought supplier knowledge about components and component ordering due to experiencing technical issues during the development process. After an extended knowledge search, a supplier made a recommendation to substitute a component in the product. The component in question was novel to Alpha and used a different technology that had the potential to resolve various technical issues. This initially changed Alpha's thought process by stimulating a new idea: *"I'm thinking we can perhaps grind [component a] into this [new component] and operate a system similar to [existing product system]. This would allow us to develop [new products] around the [new system] and give us some flexibility there." (Developer).* This resulted in a change of behaviour by the developer that would enable the new product to be modularised, opening further opportunities to develop supporting products. Alpha subsequently adopted this technology which led to the approval of a programme of work by the R&D laboratory to develop 12 new supporting products targeting new markets.

During NPD Two, Alpha sought knowledge of how the product was performing in relation to customer expectations, despite differences in the processing methods used by Alpha and the customer. Initially, Alpha received feedback the product *"was really good and it actually feels like a more expensive [product]" (Representative).* This market-related knowledge led Alpha to consider whether to *"re-label it as something else and sell it to a different market to a different customer" (Project Leader),* creating further market

opportunities. During this development, knowledge inflows conveyed the customer's application techniques, that were cross-fertilized with internal knowledge to stimulate new ideas and considerations: *"The last lot of feedback from the spray trials, I had [development chemist] looking at it again… he's come up with something else that's really good – I'm really impressed and it's cured it (technical defect) and it's made it cheaper" (Project Leader).* The feedback and associated modification of the product resulted in unexpected cost savings that were crucial to the success of the product.

During NPD Three, Gamma had experienced technical issues that caused defects in the end-product. These defects were costly to Gamma and had the potential to place the business under threat. The receipt of the initial formulations and knowledge associated with defects stimulated a new idea that resulted in a behaviour modification: *"rather than introducing too many new [components]… I thought we will also try a bit of [component] in the black that's the same [component] that's in the red and see what that's like" (Project Leader)*. This contrasted with an alternative option where Alpha would have used a familiar component to overcome the issue.

Outflows of Knowledge Leading to New Ideas

Our research also revealed outflows of knowledge resulted in the creation of new ideas externally that influenced the direction of two NPD projects. The suppliers and customers developed an understanding of product related technical obstacles and Alpha's capabilities that preceded to the creation of new ideas. During NPD One, various suppliers made recommendations to eliminate technical product defects. After exhausting all recommendations, an idea to substitute a core component within the product originated externally: *"I think that a polymeric 'grinding medium' could eventually be a better choice for the [component type]" (Supplier).* This external idea resulted in a behaviour modification by offering Alpha a previously unknown alternative option that eliminated the associated

technical issue. Subsequently, Alpha adopted the idea which contributed to the success of the development.

During NPD Three, after seeking Alpha's knowledge about component technologies, the customer suggested a component modification that would make the product more sustainable by enhancing the product's toxicology profile. This was perhaps due to the customer having a high level of interest in the development, since their existing supplier no longer wanted to manufacture the product. In doing so, however, the development made a significant leap towards completion.

Modifying Behaviours

Throughout each NPD, behaviour modifications occurred following internal knowledge flows and ideas created both internally and externally. The type of behaviour modifications differed between the projects. Some included intangible differences such as changing the way the project leader had thought about approaching an issue: *"you might have an idea of how you going to achieve something, start along that line, and then you get some outside information and it makes you change what you thought you were going to do" (Project Leader, NPD Two)*. Others included tangible changes such as changing components, component ratios, the steps components were added, or more fundamentally, the type of product being developed: *"We held a meeting to discuss the direction of the [project] after evaluating a range of options that include [Option a] and several [Option B]" (Project Leader, NPD One).* Overall, the most significant contributions to the success of the projects were of a technical, tangible nature.

During NPD One, there were 44 internal behaviour modifications following external inputs. Each modification influenced the direction of the development with differing levels of importance, but the most significant contribution had been a complete change of approach to developing the product. This change, however, corresponded with a supplier-related

knowledge inflow after an expansion of knowledge search. In this circumstance, email discussions that eventually led to a face-to-face meeting facilitated the initial knowledge transfer that led to the behaviour modification. This change resulted in a product system that was more flexible than the original intended product and supported the development of twelve new products.

During NPD Two, knowledge inflows resulted in nine internal behaviour modifications that had influenced the direction of the development. Knowledge of competitor product offerings enabled Alpha to adjust its approach to meet the cost requirements, whilst matching the application properties of the competitor's materials using physical samples that had been provided. However, the most significant behaviour modifications followed customer feedback: *"The biggest change to the product has been from the feedback on the down glossing...what we did, we took out the [component a] because it tends to leave an oily residue and swapped it for [component b]" (Project Leader)*. Once Alpha manufactured initial product samples, the customer participated in physical trials that consisted of *"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" (Project Leader)*. This feedback loop facilitated an incremental refinement of the product that led to the perfect balance of technological properties whilst achieving the cost requirements of the product.

During NPD Three, knowledge inflows had resulted in eleven behaviour modifications that had influenced the direction of the development. The most significant behaviour modification occurred once Alpha had learnt about the full extent of the product and the products application in practice: *"myself and Danny thought that we could do the final products for them rather than making the concentrate and then further mixing it" (Project Leader).* Alpha's direct contact with the customer facilitated knowledge of the full extent of processing. This led to the amalgamation of two manufacturing steps into a single process.

Consequently, Alpha experienced greater efficiency and cost savings. Other behaviour modifications included the alignment of Alpha's QC procedures with those of Gamma, resulting in a more tightly controlled product. Finally, as the development progressed, Alpha combined existing technical knowledge of a component, with the knowledge inflows of product and market requirements from Beta and Gamma, resulting in the development of a product free of technical defects.

NPD Success and New Capability Development

Engaging in OI activities during the NPD process supported Alpha in its pursuit of new capabilities to close a technological gap between it, as the focal firm, and its competitive environment. The mechanisms by which OI activities contribute to new capabilities consist of the *realization of a capability gap*, *engaging in external search* and *knowledge appropriation*. These mechanisms work in sequence, and each mechanism interacts with DC sensing and seizing abilities.

The realisation of a capability gap occurred once Alpha became aware of a market opportunity and a lack of critical resources to act on the opportunity. This realisation constitutes a sensing mechanism and, in our examples, was triggered by external engagements. Once the requirement for a capability and critical resources had been established, Alpha used OI activities to leverage external knowledge resources situated in supplier and customer knowledge domains. These external engagements led to reciprocal knowledge sharing that sometimes triggered further sensing of market opportunities.

Knowledge appropriation occurred subsequent to market and technical knowledge inflows and represented a seizing mechanism. Knowledge appropriation was observed through the creation of new ideas and behaviour modifications that also led to further sensing of market opportunities. Knowledge appropriation influenced the course and direction of NPDs and eventually contributed to their success. Thus, contributing to the renewal of the

firm's existing resource base through the creation of new resources and capabilities (Table 6). Interestingly, the process of gaining new capabilities appeared to result in additional capabilities, not associated with the original requirement of the NPD that Alpha could exploit in the future.

Table 6. New Capabilities Developed due to Engaging in OI Process

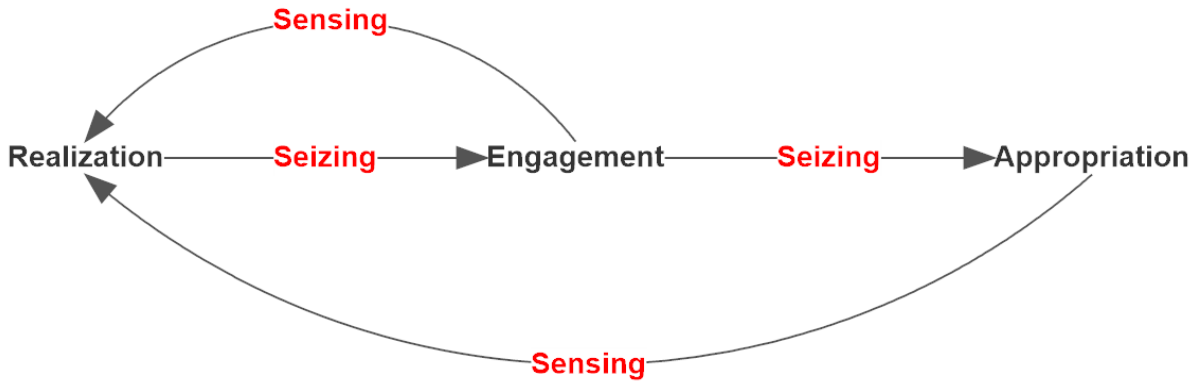
	NPD One	**NPD Two**	**NPD Three**
Capability Realised	Development of a new product (formulation & production routine) enabling the firm to sell a system of components that can be used to manufacture high-quality products and sold to various novel markets.	Development of a new product (formulation & production routine) enabling the firm to sell a product to low-cost markets, whilst achieving a specific application property.	Development of a new product (formulation & production routine) enabling the firm to sell a product into a previously unknown market.
Auxiliary Capability	Drawing on the expertise of an external consultant to obtain knowledge of a component technology resulting in increased linkages with external actors.	Developed expertise in the application of component technologies that could satisfy specific application requirements whilst reducing cost.	Developed the ability to convert a product formulation using specific machinery to more modern manufacturing machinery utilised by the focal firm.
	Developed expertise in recent component technologies that can be applied under different circumstances to capitalise on future market opportunities.	Developed ability to manipulate the application properties of a product family without affecting the aesthetic properties of the product.	N/A

Discussion

The aim of our study was to answer the research question "*How can open innovation activities contribute to a firm's dynamic capabilities by supporting the creation of firm resources?"* Our study reveals that the OI process consists of three lower-level mechanisms and that OI activities have varying degrees of interaction with each of these mechanisms. Our

analyses lead us to suggest that these three mechanisms can be integrated in a process that explains how these mechanisms interact giving rise to firm-level abilities (Figure 2).

Figure 2. Mechanisms of OI that Contribute to a Firm's DC



Our process model demonstrates that firms are able to use OI to build new capabilities through a sequential or reciprocal process determined by three underlying mechanisms. Initially, *realization* must occur, when a firm becomes aware of the requirement for a new capability that it can address through the process of NPD. Realization is a sensing mechanism that may be initiated internally or externally and occurs when previously unknown market-related knowledge is brought to the firm's attention, giving rise to awareness of a new opportunity to create value. This market-related knowledge may be conveyed and facilitated by the firm's social network or external engagements that occur subsequent to the scanning activities. However, firms may also experience realization subsequent to customer engagements, which suggests that the OI process facilitates this mechanism by retaining open communication channels with customers that enable innovating firms to learn about customer needs and preferences.

Prior studies highlight that ideas for future NPD projects may arise subsequent to knowledge search activities (Salge et al., 2013) and that resource and capability creation may

occur once firms recognise the value of new opportunities (Teece, 2007; Teece, 2014). However, we argue that realization extends the role of search activities. Our findings demonstrate that the necessary conditions to trigger realization occur both *prior* to the initiation of an OI process and also *during* an OI process. This suggests OI engagements increase the likelihood of a firm identifying new opportunities by reducing the firm's proximity to external actors who may hold valuable market-related insights (Tether, 2002). These market-related insights may then contribute market knowledge, which firms can leverage to identify capability gaps and ideas for new innovations. Consequently, we posit that the OI process enhances realization, and that a firm with proficiency in realization may experience a greater ability to sense new opportunities in support of its DC.

Once firms experience realization, they may choose to act on a newly identified opportunity through *engagement* when they gain technical awareness of a knowledge or capability gap. A knowledge gap may be market-based or technical in nature and manifest as a lack of product or process knowledge. Engagement is an iterative process that combines externally sourced knowledge with internal knowledge stock in search for new knowledge and solutions. Under such circumstances, firms may obtain both market-based and/or technical knowledge from external actors such as suppliers and customers (Laursen and Salter, 2006). During engagement, when external actors lack the required knowledge or understanding, reciprocal knowledge search may occur. Thus, representing a learning process that may grant firms access to an extended knowledge network when external actors do not possess the required knowledge or understanding. Our study demonstrates that during engagement, a firm can benefit from new market-knowledge inflows when external actors develop a greater understanding of the firm's capabilities, triggering further realization.

Prior OI studies have established inbound and outbound knowledge flows as firm-level mechanisms of OI that grant access for the firm to knowledge resources situated outside the

firm boundary (Dahlander and Gann, 2010; West and Bogers, 2014; Stanko et al., 2017). However, our findings extend the contribution of these studies by revealing that the OI process embeds inbound and outbound knowledge searching mechanisms, and these mechanisms can occur as part of a cumulative learning process that builds on reciprocal knowledge and extended knowledge networks. Therefore, echoing Caner et al. (2014), we suggest firms that engage in high levels of inbound and outbound knowledge transfer may experience higher levels of innovation outputs. Furthermore, existing research has associated a firm's knowledge recombination ability with increased innovation performance (Carnabuci and Operti, 2013) and considered outcomes of knowledge search such as ideation (e.g., Salter er al., 2015) and performance (Dahlander et al., 2016) in isolation. However, our study offers a longitudinal insight into the dynamic process by which micro-level mechanisms interact within OI activities over time, resulting in technical knowledge recombination and the recognition of new market opportunities. Consequently, we argue that OI engagement supports a firm's DC by contributing to the firm's seizing ability and may lead to further realization giving support to the firm's sensing ability.

We refer to the final element of our process model as *appropriation*, which is the process by which a firm makes knowledge and capabilities its own. Appropriation occurs subsequent to engagement and requires knowledge inflows to impact the course or direction of the OI project. Appropriation is preceded by a mutual understanding of project requirements and may occur directly or indirectly as a consequence of a knowledge creation process preceded by knowledge inflows. Direct appropriation occurs when market or technical knowledge inflows trigger an internal idea that leads to opportunity creation (Alvarez and Barney, 2007). In contrast, indirect appropriation results from the interplay between a new idea and behaviour modifications that occur at the process-level. The interplay between a new idea and behaviour modifications is bi-directional, as demonstrated by our

findings that a new idea may precede a behaviour modification or, alternatively, a behaviour modification may precede a new idea. Behaviour modifications affect the direction of the project and lead to new experiences and changes in approach. Moreover, our study demonstrates that this knowledge creation process may occur in both internal and external knowledge domains subsequent to a knowledge flow.

Existing OI research has established various factors that influence idea creation. Salter et al., (2015) established the optimum number of external knowledge sources to facilitate individuals' ideation, while Dahlander et al., (2016) suggest that individuals that build relationships with external actors are more likely to access new ideas. We contribute to this research stream by revealing that the OI process embeds a knowledge creation process that may lead to new ideas in support of firm innovations. This knowledge creation process can result in new technical knowledge by triggering behaviour modifications that impact the course or direction of OI process, or new market-related knowledge that can trigger the realization of new opportunities. Moreover, Hunter et al. (2012) suggest that individuals' creative behaviour is positively influenced by connecting to remote networks. Our research demonstrates that the OI process can provide individuals access to extended knowledge networks that contribute to product innovations via a knowledge creation process. Consequently, we argue that appropriation contributes to a firm's DC by enhancing the firm's sensing and seizing abilities through this knowledge creation process.

Theoretical Contributions

Implications for OI Microfoundations Research

Our initial contribution to microfoundations research relates to our empirical elucidation of the dynamic process by which OI leads to new resource and capability creation and we establish three mechanisms - realization, engagement, appropriation, that contribute

to a firm's sensing and seizing abilities. In doing so, we extend the general understanding of the microfoundations of organisational capabilities (Felin et al., 2015) and OI (Bogers et al., 2017). Research in this domain has identified separately project-level factors (Salge et al., 2013; Du et al., 2014; Lopez-Vega et al., 2016) and individual-level factors (e.g., Salter et al., 2015; Dahlander et al., 2016; Rangus et al., 2017, Bogers et al., 2018) that may affect firm-level innovations, and studies have recognized the need to better understand the multi-level nature of OI (Bogers et al., 2017). We complement this stream by empirically establishing process-level mechanisms of OI that contribute to a firms' DC. By offering a process-level perspective on OI microfoundations, this opens new avenues for research such as exploring how project-level factors, such as the management approach to OI projects (Du et al., 2014), or individual-level factors, such as relationships with external actors (Dahlander et al., 2016), may or may not affect process-level mechanisms. Interesting questions remain concerning how a formal or informal management approach might impact the innovation process that occurs during appropriation and how this impacts realization. Moreover, while not central to our study, our findings have prompted us to consider how relationship building could affect the speed at which external actors can understand requirements. This might provide firms with indications about how to accelerate engagement and appropriation and contribute to quicker resource and capability renewal. Hence, an interesting avenue for further research is to explore the microfoundational mechanisms that set the right pace in OI collaborations in pursuit of capability renewal.

Implications for OI and DC Research

Our research also has implications for both OI and DC research. Prior research has suggested that DC are vital to firms in markets with high rates of technological change (Teece, 2007). In these contexts, firms with DC identify new technological opportunities through the development of scanning and monitoring competencies that manifest as sensing

abilities (Teece, 2014). However, our study reveals that it may also be beneficial to view DC as a strategy for firms to cope with incremental change. From this perspective, OI becomes a bundle of mechanisms that enable the firm to renew their existing capabilities by leveraging external knowledge resources. These mechanisms and their interactions represent inter-firm heterogeneity in their ability to operationalise sensing and seizing abilities that lead to DC. As such, a firm should strive to develop OI capabilities that contribute to firm-level sensing and seizing abilities and therefore, the firm's DC.

We extend earlier research on the relationship between OI and DC (Ahn et al., 2018) by offering a more fundamental perspective through the microfoundations lens when compared those studies that examine the relationship between these concepts at the firm-level. As such, our study captures the relationship between mechanisms previously examined at the firm-level (e.g., inbound/outbound knowledge flows) by shifting the perspective to consider how these mechanisms interact from within the OI process at the micro-level, giving rise to firm-level abilities. Consequently, our research shifts the emphasis away from examining such mechanisms in isolation to a dynamic process whereby multiple micro-level mechanisms interact over time.

Implications for Absorptive Capacity Research

Finally, although not central to our study, our findings provide insight into several process-level mechanisms that facilitate the integration of knowledge resources during OI. Existing research has established mechanisms linking OI to a firm's absorptive capacity (Zobel, 2017). Our study empirically demonstrates that OI is an important vehicle for mobilizing knowledge across firm boundaries and, therefore, plays a role in altering the absorptive capacity of firms (Cohen and Levinthal, 1990). Indeed, our findings reveal that realization, engagement and appropriation are critical micro-level mechanisms that trigger the firm's absorptive capacity through an intricate process and enable it to learn and bring new

knowledge from external sources into the organisation. In this respect, our empirical study has brought some important micro-foundational elements to the conceptual understanding of how firm level capabilities develop from microfoundations (Lewin et al. 2011).

Moreover, prior studies of absorptive capacity have highlighted the role of individuals' perspectives adopted in contributing to the creation of new and innovative ideas prior to innovation activities (Distel, 2019). We extend this understanding by establishing a knowledge creation process that underlies new idea creation *during* NPD. This process is guided by changes to an individual's thought processes that manifest as behaviour modifications that influence the way that individuals choose to approach part of a NPD.

Limitations and Future Research

Although we made every effort to conduct a rigorous study, our paper is not without limitations. The data from this study were obtained from a single manufacturing organisation operating within a specific industry sector. Therefore, it is entirely possible that the firm has some unique characteristics. Future studies could elaborate on the relationships between the mechanisms we identified, or groups of elements of our model in other settings. For example, these could include: non-SMEs; non-manufacturing firms; firms that operate in different industry sectors; and firms that have other governance and ownership structures. We identified several relationships, such as the relationship between inbound knowledge flows, new idea creation, behaviour modifications and outbound knowledge flows. These appear to operate in sequential or reciprocal relationships. Examining these relationships further will help to shed light on those behaviours that are likely to lead to a more favourable outcome and those that may lead to failure.

Our research has focused on an essential organisational process, namely that of NPD. However, other distinct mechanisms of inbound, outbound and coupled OI exist and all of these can potentially contribute to the firm's DC in diverse ways. As such, future research

could explore the relationships between these different OI mechanisms to investigate further microfoundations that link OI to the firm's DC.

Conclusion

The aim of our study was to answer the question of how OI can contribute to a firm's DC. By adopting a microfoundations perspective and examining the process of NPD in a rich research setting, we were able to identify three underlying mechanisms of OI —realization, engagement, appropriation—that contribute to the creation of firm resources and the firm's DC. To our knowledge, this is the first attempt to uncover microfoundations underlying the renewal of firm resources through OI activities. Our study reveals that each mechanism links the process of OI to a firm's DC by sequentially and reciprocally altering the firm's abilities for sensing and seizing opportunities. Sensing and seizing abilities can help address previously ignored market domains that were not accounted for in a firm's current strategy. Thus, supporting incremental capability and resource creation through fundamental activities that underpin the DC framework. The implication of using OI activities during the NPD process was a reorientation of the liability of ownership and control of resources, to one of inclusion and participation (Hautz et al., 2017). Under these circumstances, OI shifts the focus of the DC framework from the internal perspective of applying resources that firms own, to relational resources that the firm can exploit. Consequently, OI enriches firm capability development with external knowledge resources, contributing to a firm's DC.

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