# **RESEARCH PAPER**

# Toward a Relational View of Organizational Innovation: Learning from Previous and Subsequent Stages of Innovation in Large Biopharmaceutical Firms, 1990–2006

# Eric Dahlin

Sociology Department, Brigham Young University, Provo, UT, United States

# ABSTRACT

The paper draws on insights from relational sociology to develop a relational view of organizational innovation which suggests that feedback between stages of innovation may occur regardless of whether they precede one another, and activities at different stages may have reciprocal effects. Regression models based on a sample of 113 large biopharmaceutical firms demonstrate that firms with products in alternative stages of innovation are associated with having products in the focal stage. The key findings from the regression analysis are that product development generates positive feedback for product implementation and *vice versa*, and engaging in activities at multiple, alternative stages simultaneously generates benefits at the focal stage. The reciprocity between stages provides compelling evidence for the importance of viewing innovation through the lens of relational theory. Interviews with industry informants illustrate the fluidity that exists between innovation stages and the importance of fostering social interactions and communication between organizational members involved in innovation for fostering success across stages.

# Introduction

Economic history is littered with examples of technologically superior alternatives that remained in product-development purgatory, failed horribly upon reaching the market, or existed for decades in obscurity before eventual adoption on a large scale. Successful innovation is frequently elusive because of the wide-ranging activities required for a novel object to progress from a new idea to something that is prototyped and tested by potential users and then manufactured, marketed, distributed, and eventually sold on the market. The innovation literature reflects this diversity of innovation-related activities by examining, among other things, R&D expenditures (e.g. Cohen and Levinthal, 1990), patenting (e.g. Owen-Smith and Powell, 2004), new product development (e.g. Katila and Ahuja, 2002) and diffusion (e.g. Tolbert and Zucker, 1983).

Though innovation scholarship has yielded myriad insights regarding the factors that foster success for each of these activities – explanations of success at particular stages typically emphasize inter-organizational networks (e.g. Powell *et al.*, 1996), organizational practices (e.g. Brown and Eisenhardt, 1997), and institutional arrangements (e.g. Tolbert and Zucker, 1983) – it seldom examines the links between stages of innovation that may impact the overall success of a product. Stated differently, outcomes at one stage of innovation may affect success at other stages. Prominent frameworks in the management literature that underscore the importance of each stage for overall success include Hansen and Birkinshaw (2007) and Cooper (1990, 2001, 2008), and describe innovation as a series of interrelated activities in which deficiencies at one stage prevent success across all stages. While both Hansen and Birkinshaw and Cooper provide intuitive appeal and anecdotal evidence that activities at one stage affect other stages, these approaches have yet to conceptualize the general conditions in which synchronies or asynchronies exist between each stage or systematically assess whether, in fact, outcomes at each stage affect success at subsequent or preceding stages.

To address this gap, I draw on insights from the innovation studies and relational sociology literatures and apply their insights to understand the links between the stages of innovation in the biopharmaceutical industry.<sup>1</sup> One strand of literature within innovation studies shows that some firms demonstrate persistent innovation, while others do not. Some firms develop innovative capabilities that allow them to maintain a relatively higher level of innovative output. Generally speaking, past innovative proficiencies foster higher levels of subsequent innovative output. Nevertheless, this approach is silent on the relationship between activities at various stages of innovation. Another view, the relational view in sociology, offers insights that help provide a framework for moving forward. The relational view suggests that the meaning of human action and the subsequent identities that result from social interactions unfold over time (Emirbayer, 1997; Mische, 2011; Erikson, 2013). Because identities and relationships are dynamic, individual behaviour in the present is informed by the perpetual reinterpretation of past experience, current contextual contingencies, and expectations about obtaining the desired results in the future (Emirbayer and Mische, 1998). The impact of temporality on agency as articulated in the relational view - based on human understandings that are affected by the past, present, and future - serves as a source of understanding about the potential links between the stages of innovation. The relevance for innovation is that stage-specific activities in the present may also be informed by knowledge and experience gained in previous stages and projections about activities required in subsequent stages. Outcomes at one stage of innovation may generate synchronies that are beneficial or asynchronies that are detrimental to activities at other stages. While existing frameworks presume that outcomes at one stage are dependent on preceding stages (Cooper, 1990, 2001, 2008; Hansen and Birkinshaw, 2007), I go a step further by proposing a relational view of innovation that provides a lens for illuminating whether feedback occurs between stages of innovation.

The results for the present study are based on data from interviews with key industry informants and a quantitative analysis of a sample of 113 firms in the biopharmaceutical industry in the United States. The key findings from regression models demonstrate, first, that firms with products at the development stage generate positive feedback for products at the implementation stage and *vice versa*; because tasks required for success at later stages tend to be administrative rather than scientific that generate complementarities. Second, the effects of interaction terms in the regression models indicate that simultaneously having products at multiple stages of innovation generates cumulative advantages for success at the focal stages. Interviews with industry informants illuminate the fluidity that exists between innovation stages. More effective innovators foster social interactions that generate communication about how activities at one stage may provide a boon to activities at other stages.

<sup>&</sup>lt;sup>1</sup>This paper focuses on the perspectives elaborated in the innovation studies and relational view literatures because of their usefulness in understanding the links between stages of innovation. This paper is not intended to provide a summary of the vast research on innovation in the biopharmaceutical industry. Additional explanations that are not discussed but that impact innovation success include a firm's scientific orientation (Maurer and Ebers, 2006) or market orientation (Appiah-Adu and Ranchhod, 1998); collaborations between corporations and universities and research and government institutions (Audretsch and Stephan, 1996; Blumenthal *et al.*, 1986; McMillan *et al.*, 2000; Owen-Smith *et al.*, 2002; Pisano, 2006); institutional arrangements (Pisano, 1991; Casper and Matraves, 2003); and geographic location and regional clusters (Cortright and Mayer, 2002; Gertler and Levitte, 2005; Owen-Smith and Powell, 2004; Porter *et al.*, 2005).

# Background

#### Stages of innovation

That firms must demonstrate some degree of proficiency at each stage of innovation to sustain success has been argued by Hansen and Birkinshaw (2007) in describing the innovation value chain. The innovation value chain is a framework that views innovation as an integrated process involving a variety of competing and complementary tasks across the stages of innovation. The innovation value chain refers to a three-stage process or chain of activities that includes idea generation, development, and diffusion. Sources of idea generation may include the focal business unit, multiple-unit collaborations, and external sourcing from strategic alliances or the industry at large. The next stage, idea development, involves converting ideas into usable products. Finally, diffusion consists of distributing products to relevant constituencies or customers in the market. For Hansen and Birkinshaw, management's task is to diagnose the stage at which the firm is deficient and to implement stage-specific interventions aimed at improving these deficiencies.

Another approach that views innovation as interdependent stages is the Stage-Gate model developed by Cooper (1990, 2001, 2008). The Stage-Gate model is conceptualized as a series of stages and gates through which new products progress. The stages include discovering and assessing new ideas; gathering information about a product's potential and feasibility; and developing, testing, and launching the product. At each stage, products are evaluated and a 'go or no go' decision is made that determines whether the product should proceed to the next stage or be terminated. The imagery of the Stage-Gate model is linear and sequential, though Cooper (2008) acknowledges that the product development process is, in fact, nonlinear. He notes that products may skip stages, stages may overlap, or activities at different stages may occur in parallel, and outcomes at one stage affect success and failure at other stages.

The innovation value chain and Stage-Gate approaches are intuitively appealing and underscore the interdependence of innovation stages. Each approach presumes that activities at each stage play a role in overall product success and, by implication, how success at preceding stages affects subsequent stages. Even so, advocates of these perspectives have yet to theorize which stages may generate positive or negative feedback with respect to preceding or subsequent stages. While extant research does provide detailed case studies illustrating that activities at one innovation stage influence success at other stages (Brown and Eisenhardt, 1997; Kaplan and Orlikowski, 2013; Van de Ven *et al.*, 1999; Garud *et al.*, 2011a; Garud *et al.*, 2011b), this strand of research is still evolving and has yet (1) to provide the rationale for which stages influence others or (2) to assess systematically whether outcomes at one innovation stage have beneficial or deleterious effects on outcomes at preceding or subsequent stages. Thus, more research is needed to elaborate and advance the rationale about why success at one particular stage may have positive or negative effects on success at other stages.

One could imagine conflicting but reasonable expectations about the impact of early-stage activities on success at the later stages and vice versa. On the one hand, devoting energy to activities at one stage may exhaust precious resources that could have been devoted to activities at later stages. For instance, the need to dedicate an inordinate amount of temporal or financial resources to activities related to product development (such as developing prototypes, improving design features, testing functionality, and ensuring user safety) may prove to be detrimental to activities at other stages. On the other hand, product-specific knowledge generated at earlier stages about potentially beneficial features or uses may serve as a reservoir of knowledge to be leveraged at later stages, even if its intended relevance was not recognized when the product was initially developed. Take the case of 3M's brightness enhancement film (BEF), a thinly layered optical film used to improve the visual display of laptop computer screens. BEF was invented in the 1960s and had multiple intended uses, including traffic signs. However, it lingered in development without success until the 1980s when engineers discovered it could be used for laptop screens. Recounting BEF's product history, Garud *et al.* (2011b, p.754) observe that 3M was able to ""stretch out time" until

the market application materialized'. Eventual success was not realized until a suitable and commercially viable application became available and was recognized by engineers. For years, the progress of BEF through the stages of innovation was curtailed when there was no apparent implementation for the newly invented product, but then accelerated once the market changed and engineers realized its utility. The previous mismatch between product development activities and implementation opportunities was reversed once laptop screens became a viable application.

# Innovation studies

The field of innovation studies (for overviews see Fagerberg and Verspagen, 2009; Fagerberg *et al.*, 2012; Martin, 2012) provides a backdrop for examining products that progress through the stages of innovation. Fagerberg *et al.* (2012, p. 1132) define innovation studies as 'the scholarly study of how innovation takes place and what the important explanatory factors and economic and social consequences are'. Scholarship within this field focuses on the question posed by Hawkins and Davis (2012), how are novel ideas transformed into products that organizations can commercialize and end users adopt? This question recognizes that the innovation journey (Van de Ven *et al.*, 1999) involves a transition from a novel idea to product appropriate for use by end users. It also implies that different factors must necessarily be involved in the transition (see Hansen and Birkinshaw, 2007; Cooper, 1990, 2001, 2008).

One line of research in the innovation studies literature, the technological innovation systems (TIS) framework, notes that different phases characterize the successful development of a novel technology (Carlsson and Stankiewicz, 1991; Bergek *et al.*, 2015; Markard *et al.*, 2012; Bento and Wilson, 2016). The TIS is a comparative historical approach that seeks to explain 'the emergence *and* growth of an innovation system around a particular technology' (italics added) (Bento and Wilson, 2016, p.96). An innovation system, which is conceptually similar to a socio-technical system (Geels, 2002, 2005), refers to a particular technology as well as to the actors, networks, and institutions that contribute to its development and support its adoption and diffusion. Actors include organizations in the supply chain (suppliers, manufacturers, and distributors) and also NGOs, associations, research centres, and institutes. Networks consist of inter-organizational communities that share knowledge, or coalitions that promote the technology. Supportive institutions may be formal – consisting of policies, regulations, or industry standards – or informal, such as user practices, cultural meanings, and social norms (Markard, 2020).

In research on technological innovations systems (TIS), the formative phase is the first phase that characterizes technological innovation systems.<sup>2</sup> In this phase, a variety of competing ideas exist about a particular technology and how it should develop, experimentation occurs, and a standard design emerges. In the second phase, the growth phase, development shifts to production and distribution as the technology diffuses to the mass market (cf. Bergek *et al.*, 2008). Case studies in a number of settings illustrate these two phases of development for technological innovation systems and the role of supportive actors, networks, and institutions. Such settings include the advent and implementation of natural gas used for heating in the Netherlands and district heating in Denmark (Roberts and Geels, 2019a), automobile transportation and specialized wheat agriculture in the United Kingdom (Roberts and Geels, 2019b) and natural gas fuelled automobiles in the Netherlands (Suurs *et al.*, 2010).

While TIS scholarship typically takes place at the industry level, examining the development and success of the innovation itself and how it unfolds over time (cf. Abernathy and Clark, 1985;

<sup>&</sup>lt;sup>2</sup> Several scholars identify additional stages of development for technological innovation systems. Other stages include nascent (existence of a variety of technological concepts), emerging (agreement on a small number of designs), strengthening (convergence on a dominant design), and maturation (mass production of technology) (Bento and Wilson, 2016).

Arthur, 2007; Teece, 1986), one stream of innovation studies scholarship occurs at the organizational level. Early studies in this stream focus on organizational routines and learning processes. Routines are persistent patterns of behaviour that constitute an organization's memory or repository of knowl-edge (Nelson and Winter, 1982). The organizational learning view elaborates the ways in which routines are developed and impact employee behaviour and organizational outcomes (Argyris and Schon, 1978; Levitt and March, 1988). These routines become informally and formally inscribed into the organization's structure. Routines may be inscribed into the organization's structure through the emergence of an informal culture or formally through the development of manuals, goals, and reports.

More recent efforts, represented by the persistence of innovation view (Roper and Hewitt-Dundas, 2008; Peters, 2009; Triguero and Córcoles, 2013; Tavassoli and Karlsson, 2015), draw on organizational learning approaches to argue that accumulated organizational knowledge forges connections between past and future innovation activities. Knowledge is not a finite resource. It can be used in new ways and reused in different situations (Katila and Ahuja, 2002). Knowledge accrues from past innovation successes, generates economies of scale for innovative firms, and results in subsequent innovation success. Empirical research supports the persistence of innovation view, but also includes a number of variations on the main theme. For instance, Cefis (2003) and Cefis and Orsenigo (2001) find that innovative firms and non-innovative firms have a high probability of remaining in their respective categories as innovators and non-innovators. Findings from Clausen et al. (2012) demonstrate that different types of innovation strategies affect subsequent innovation. These strategies include market-driven, R&D intensive, and science-based strategies. Ganter and Hecker (2013) observe that product innovation, but not innovation in organizational processes, positively influences subsequent product innovation and organizational process innovation. Of four types of innovation - process, product, marketing, and organizational - Tavassoli and Karlsson (2015) find that product innovation generates the strongest persistent behaviour.

The innovation studies scholarship provides a broad rationale for this paper's analysis of the stages of innovation, but it also provides opportunities for further research. The TIS approach highlights multiple phases – the formative and growth phase – that constitute innovation and the persistence of innovation view identifies the importance of positive feedback within the innovation process such that the success of past novel products influences the generation and success of subsequent ones. Nevertheless, more work remains. While these approaches recognize multiple stages and the importance of positive feedback across products, they insufficiently theorize the links between stages of innovation at the organizational level. That is, these views have yet to develop explanations for why activities at different stages in the innovation process have mutually beneficial or deleterious effects. To this end, this paper turns to the relational view developed in sociology.

#### Toward a relational view of organizational innovation

The relational view advanced in sociology is used to develop a framework for better understanding the links between innovation stages. Proponents of the relational view conceive of actors as constituted by relationships (Emirbayer, 1997; Mische, 2011; Erikson, 2013). According to this view, meanings and identities for actors are not detached from social interaction, but develop concomitantly with the relationship (Mische, 2003; White, 2008; Fuhse, 2009). '[T]he meaning one individual assigns to another is the basis of any relationship; in fact, the absence of meaning could easily be understood as the absence of a relationship – when you have no expectations or knowledge of another individual' (Erikson, 2013, p.227). As an example, the role of hunter is meaningless without the presence of the hunted, both of whom are connected through the act of hunting (Dewey, 1960).

The relational view in sociology can be compared and contrasted to other prominent perspectives. It can be compared with the relational approach promoted in the management literature. This approach emphases the importance of interorganizational networks for a variety of firm-level outcomes, including innovation (cf. Powell *et al.*, 1996). Dyer and Singh (1998) identify four primary advantages of interfirm networks. Advantages include developing relationship-specific assets, knowledge exchange and joint learning, combining complementary resources and capabilities, and governance structures that effectively reduce transaction costs. The relational view in sociology can also be contrasted with rational-choice theorists' views of individuals who act under game-theoretic conditions and display relatively autonomous decision-making capacity. For rational choice theorists, decision-making is shaped by the presence of others and expectations about rewards for particular decisions, but the capacity to decide is not given to the individual by others. Accordingly, the source of action is a singular expression that originates within the individual.

Much research informed by the relational perspective has mapped cultural meanings, categories, and identities onto social interactions (Mohr, 1994; Mische and Pattison, 2000; McFarland, 2001; Mische, 2003; Smilde, 2005; Gibson, 2005; Yeung, 2005; McLean, 2007; White, 2008; McFarland et al., 2013). However, an aspect of the relational view that is particularly relevant for the present study involves the role of temporality as related to social outcomes. Relational scholars view relationships and the related outcomes 'as preeminently dynamic in nature, as unfolding, ongoing processes rather than static ties among inert substances' (Emirbayer, 1997, p.289; see also White, 2008). Since social processes are dynamic, individual identities can conflict in the present, change over time, and shape future action. In their articulation of agency, Emirbayer and Mische (1998) conceive of action as the confluence of present conditions, past experience, and anticipation of the future. As Emirbayer and Mische (1998) explain, first, 'actors attempt to reconfigure received schemas by generating alternative possible responses to the problematic situations they confront in their lives'. Then, as actors are '[i]mmersed in the temporal flow, they move "beyond themselves" into the future and construct changing images of where they think they are going, where they want to go, and how they can get there from where they are at the present' (p.984). Actors continually reinterpret past experience and current surroundings while their understanding evolves about the appropriate action for achieving anticipated ends in the future.

The temporal nature of human action in which the present is informed by the past and future is apparent in market behaviour as well. White's (2002) relational view of production markets elucidates the reason why firms simultaneously consider upstream and downstream activities for products in the supply chain.<sup>3</sup> Production markets consist of suppliers, producers, and purchasers that manage uncertainty. In contrast to the orthodox view of exchange markets structured by the interplay of supply and demand as mediated by the price mechanism, White suggests that producer firms, which manufacture and transform materials from suppliers, determine the quality and quantity and goods to produce based on the performance of others in the industry. Producer commitment to supply a specific volume of goods influences the extent to which firms engage in other activities, such as procuring inputs from suppliers and manufacturing. White (2002, p.28) states, 'Producers of most lines of goods or services commit to a volume of output as they arrange inputs needed for the next period. ... [T]hese commitments become reflected in their investments in specialized infrastructure and equipment.' A firm's commitment to production activities downstream in the supply chain becomes inseparably connected to its upstream activities related to input materials, infrastructure, and equipment requisite for production. White's work illustrates the nonlinear nature of temporality for upstream and downstream supply chain activities, with activities at alternative supply chain stages being considered when making decisions about activities at the focal stage within the supply chain, which contrasts with the orthodox view that the price, based on supply and demand, drives product success.

Though the relational view is typically applied to the setting of human interaction and interpersonal relationships, White applies the relational lens to understanding the action of organizations

<sup>&</sup>lt;sup>3</sup> The concepts of upstream and downstream come from supply chain management. Supply chain management is concerned with managing the flow of materials from suppliers (who are upstream in the supply chain) to customers (who are downstream in the supply chain) (Frohlich and Westbrook, 2001).

in the supply chain. Firms that produce goods 'act' by deciding what to produce and how much of it to produce. This conception of organizations as actors is consistent with the view of students of organization (Coleman 1974; Meyer 2010; King *et al.*, 2010; Bromley and Sharkey 2017). Corporations are not only regarded by the law as 'natural persons' that are afforded certain rights (Pollman, 2011), but as Bromley and Sharkey (2017, p.4) explain, organizations also possess 'identity, sovereignty, and the capacity for purposive action'. In their analysis of 300 annual reports from 1960 through 2010, they find that firms increasingly over time represent themselves as entities with values, agency, and responsibility for a wide range of social issues. King *et al.* (2010) similarly argue that organizations are actors. Organizations demonstrate sovereignty with their power to sue or be sued, enter into contracts, hire and fire employees, and reward behaviour or impose sanctions. Organizations also possess unique corporate cultures, values, and identities that are distinct from other organizations and independent of their members (Whetten, 2006; Bromley and Sharkey, 2017).

For the purposes of this paper, the relational view's supposition that action in the present is influenced by memories of the past and expectations about the future is critically important. This insight is applied to innovation by noting the temporal continuities that exist between activities at different innovation stages. Innovative activities in the present may be informed or constituted by knowledge and experience gained in previous stages and projections about activities required in subsequent stages, as well as experience firms gain from other products that have already progressed through subsequent stages. Obfuscating the boundaries between stages of innovation challenges traditional notions of time by highlighting the temporal complexities that can disrupt or enhance links between stages and the overall innovation process. According to Garud et al. (2013, p.793), temporal complexity, which refers to '[m]ultiple temporal rhythms [that] generate asynchronies in the emergence of different elements of the innovation and the infrastructure required for its development and implementation', can produce unanticipated challenges and lead to uneven progress through stages that either stifle or accelerate success. Products need not progress through the stages of innovation in a linear fashion and temporal complexity in the innovation process can create asynchronies between stages of innovation that have deleterious effects when activities at various stages deplete temporal and financial resources that could be deployed elsewhere. Garud et al. (2013, p.775) refer to such asynchronies in the innovation process as cycles of divergence, which are animated by the 'expenditure of resources (people, time, ideas and money) above and beyond the system's normal sustenance'. Knowledge, resources, time, or routines and capabilities required to be successful at one stage simultaneously can produce diminishing returns at other stages that are challenging to overcome (Van de Ven et al., 1999; Hansen and Birkinshaw, 2007; Garud et al., 2013). Alternatively, activities at different stages can be synchronous - when activities at one stage simultaneously benefit other stages by generating complementarity. Resources are not always finite, and the benefits of activities at different stages of innovation need not be stage-specific. Some resources, such as information, may be abundant and used many times over. Knowledge embodied in patents is used repeatedly in new products (Katila and Ahuja, 2002), for example. Firms may also use some types of knowledge repeatedly when manufacturing, distributing, marketing, or selling different products to end users. In this way, product-specific knowledge or capabilities can span traditional notions of time in the innovation process.

Having products in earlier stages of innovation increases the chances that firms will have products progress to successive stages. More products at the invention stage provides a pipeline of products to be developed and, in turn, sold on the market. Firms may also leverage experience with a product at a preceding stage that is subsequently used for another purpose. Therefore, if an already-invented product is used for another application, it is (typically) unnecessary to reinvent or redevelop it, thus eliminating the need to regress to previous stages of innovation. As Teece (1982, p.45) states, '[A] firm's capability lies upstream from the end product – it lies in a generalized capability which might well find a variety of final product applications.' Examples abound. In 2001, Acadia Pharmaceuticals began testing the drug Pimavanserin in clinical trials to treat schizophrenia.

Two years later, Acadia tested the same drug in a new set of clinical trials to treat a different medical condition, Parkinson's disease. W. L. Gore & Associates has applied polytetrafluoroethylene (PTFE) as an effective coating for a wide range of products, including medical implants, gaskets, and clothing.<sup>4</sup> Apple reuses a host of technologies, designs, and manufacturing capabilities across devices, such as cameras, music players, electronic messaging, and internet browsing capabilities.

It is intuitive to suppose that having products in previous stages increases the number of products in subsequent stages, which leads to the first two research questions:

Research Question 1: Is having one or more products at the invention stage positively associated with products at the product development stage?

Research Question 2: Is having one or more products at the development stage positively associated with products implemented?

The relational perspective has the potential to provide a more complete account of innovation success across stages by illuminating the possibility for the coevolution of activities at different stages, regardless of whether one stage immediately precedes the other. Accordingly, an additional view-point should be considered with respect to the potential for reciprocity between activities at the product development and implementation stages. Different types of tasks characterize each of the stages of innovation, but the activities associated with product development and product implementation are more likely to be complementary compared with product development and product invention or compared with product implementation and product invention. The reason is that the types of activities typically shift in nature from scientific in the earliest stage to administrative in the later stages. Invention activities often involve scientific or technical discovery as firms search for novelty. Then, the need for technical or scientific discovery typically declines in the later stages, when administrative requirements have a tendency to increase (Rothaermel and Deeds, 2006).

Once invented, developing a usable product is likely to require a greater degree of infrastructure and administrative capacity. Firms with the capacity to carry out product development are inclined to possess the infrastructure to handle the administrative demands required for product implementation. In addition to investments in large-scale production, implementation activities include marketing and establishing, managing, and coordinating efforts between distribution channels and retail outlets. Presumably, firms with products at the final stages in the innovation value chain are older and larger than their counterparts with relatively novel products at the earliest stage. Older firms have more defined roles and established routines for communicating and have stronger relationships between employees and customers (Stinchcombe, 1965), all of which aid the execution of administrative routines. With respect to older firms in the high technology industry, Sorensen and Stuart (2000, p.85) explain that they 'will have perfected the routines, structure, incentive programs, and other infrastructure that are needed to develop new technologies [product development] and bring them to market [product implementation]'. Additionally, Tushman and Anderson's (1986) study shows that older firms have more information-processing capabilities that promote 'competence-enhancing' innovation that represents incremental improvements to existing technology (i.e., development) rather than radically new 'competence-destroying' innovation (i.e., invention).

The activities that commonly accompany the search for novelty in the early stages and the administrative tasks that typically comprise the later stages are analogous to the difficulties inherent in balancing exploration (exploring novel alternatives) and exploitation activities (building on existing competencies) (March, 1991). Whereas product development and implementation involve modifying an existing idea or object (i.e. exploitation), product invention implies searching for possible solutions (i.e. exploration). Exploration and exploitation consist of different logics (Gupta *et al.*, 2006) that are

<sup>&</sup>lt;sup>4</sup>See www.gore-tex.com/remote/Satellite/home (accessed May 2020).

sustained by different organizational cultures, routines, and capabilities that may be difficult to reconcile (Sorensen, 2002; Andriopoulos and Lewis, 2009). Since organizations exhibit structural inertia (Hannan and Freeman, 1984), exploration and exploitation processes become self-reinforcing over time to the exclusion of the other.

The differential tasks of scientific discovery versus administration, as well as the logic of exploration that is characteristic of invention compared with the logic of exploitation characteristic of development and implementation, lead to the conceptualization of a reciprocal relationship between development and implementation in which products in development positively impact products implemented and *vice versa*. This leads to two further research questions:

Research Question 3: Is having one or more products at the implementation stage positively associated with the number of products developed?

Research Question 4: Is having one or more products at the implementation stage negatively associated with the number of products invented?

The research questions so far assume that firm heterogeneity in resources and capabilities leads to varying degrees of success (or failure) across each stage of the innovation value chain. The problem for the organization is that each stage presents different obstacles to the overall success of a product. The solution to the problem, then, is to find complementarities between stages or simply to find a way to acquire new and different organizational resources or expertise that enhance the product's likelihood of success at the next stage. However, another possibility exists. In addition to the expectation that activities at a single stage may be linked to success at another stage, cumulative advantage may exist for firms across the stages of the innovation. That is, some firms may be able to create advantages that go beyond any particular stage of innovation.

Saloner *et al.* (2001), for instance, discuss the possibility of cumulative advantage that results in engaging in R&D: 'a firm develops a stock of knowledge that enables those within the firm to innovate more quickly because they are already engaged with the current technology. . . . [T]he payoff from R&D has a cumulative nature that implies an incumbency advantage' (p.225). This incumbency advantage is illustrated by Design Continuum, a very successful design firm. Design Continuum designed the Reebok Pump basketball shoe relatively quickly when engineers who had previously worked with medical equipment and an inflatable splint combined intravenous bags with a basketball shoe (Hargadon, 2003). Apple has benefited from its expertise upstream (i.e. revolutionary hardware and software technology) and downstream (i.e. industrial design and user interface) in the value chain to develop a series of similar products (iPod, iPhone, iPad) in a relatively short time.

Since research has yet to examine the combined effects of multiple, alternative-stage activities, it is unclear whether these effects will yield positive or negative effects on success at the focal stage. Engaging in activities at several other stages may syphon valuable resources from activities at the focal stage or produce cumulative advantages that result from the flow of complementary knowledge of upstream and downstream activities. Therefore, the analysis below examines the possibilities that firms with products in both the invention and development stages concurrently will influence product implementation, firms with products in both the invention and implementation stages will influence product development, and firms with products in both the development and implementation stages will influence product invention.

#### Method

#### Quantitative analysis

The sample of firms examined in the quantitative analysis comes from a proprietary database compiled by Recombinant Capital (Recap), a consulting company that gathers detailed information about strategic alliance partners and drugs in firms' product pipelines for private and public, US and international companies.<sup>5</sup> Drug-related data include information about the drugs, the medical conditions that the drugs are intended to treat, and the dates the drugs reached various phases of clinical trials (phase I, phase II, phase III, phase IV), drugs under review at the Food and Drug Administration (FDA), and drugs that reached the market. Recap data are culled from publications such as 10-K forms and other forms submitted to the US Securities and Exchange Commission (SEC), annual and industry reports, and other media sources, such as the popular business press.

The sample was found by searching in 2008 for US publicly traded firms in the Recap database. The search was limited to publicly traded biopharmaceutical firms headquartered in the United States. Recap data are more readily available for these firms and drugs; international firms are subject to different regulatory requirements and cultural arrangements, which are difficult to account for; and additional firm-level data collected and included in the analysis below are difficult to acquire for private and international firms. The search of the Recap database yielded 113 firms. The unit of analysis is the firm-year, and the period under investigation is 1990 through 2006.

The Recap database has strengths and weaknesses. It is a valuable data source because data on products in various stages of innovation are generally difficult to obtain. Information on a firm's product portfolio is often proprietary and requires the firm to document details about product development along the way. The primary weakness is that Recap gathers data from public sources. So, the firms included in the database are more likely to be large and successful, firms for which information is more likely to be available. The extent to which firms in the Recap sample in 2006 differed from public firms listed in Bioscan (2006) (another industry publication containing information on clinical trials for the year 2006) was calculated. First, there was no statistically significant difference in the average number of employees in the Recap and Bioscan samples. But average sales for Bioscan firms were \$US800 million and the Recap average was \$US1,171 million (t = 2.714, p-value = 0.007) and average total assets for Bioscan firms was \$US1,218 billion while the Recap average was \$US1,820 billion (t = 2.851, p-value = 0.004). The difference in sales and total assets is statistically significant. Thus, based on these measures, firms in the Recap sample are not necessarily larger, but they are more successful than other publicly traded firms in the industry.

#### Measures

Garud et al. (2013) define the stages of innovation as invention, development, and implementation. Invention refers to generating a novel idea, development denotes elaborating the idea, and implementation is the adoption of the idea. Following Garud et al., three dependent variables were used to depict these broad stages of innovation. Product invention is measured as the number of drug discovery projects undertaken by a firm. For drug discovery projects, scientists search for new scientific knowledge in the form of a chemical entity with the potential to become a drug and determine the appropriate dose and whether tablets or capsules would constitute the better form (Zanders, 2011). Data for this variable were collected for the firms in the Recap sample from IMS Health's R&D Focus proprietary database. IMS Health is a leading consulting company in the pharmaceutical industry, and R&D Focus is an excellent source for data on the discovery stage, which can ordinarily be difficult to obtain because of intellectual property concerns. IMS Health data are collected from various sources that include government agencies, industry conferences, scientific publications, and contacts with industry professionals (Hoang and Rothaermel, 2010). Product develop*ment* is measured as the number of drugs in any phase of clinical trials for the firms in the sample. A brief description of the clinical trials process illustrates the administrative infrastructure required for carrying out activities at this stage. Clinical trials consist primarily of three phases and are

<sup>&</sup>lt;sup>5</sup> The Recap database has been used in several other studies of product development and strategic alliances in the biopharmaceutical industry. Prominent studies include Rothaermel and Thursby (2007) and Hernandez and Shaver (2019).

overseen by physicians and the drug company to monitor the progress of volunteers. Phase 1 tests the drug on 20 to 100 healthy volunteers to determine whether it is safe for human consumption. Phase 2 tests different doses of the drug on a larger group of patients (anywhere from 100 to 500 who are affected by the medical condition) from the target population to evaluate the drug for potential side effects and effectiveness. Phase 3 tests the drug's effectiveness on a larger number of patients (from 1,000 to 5,000 from various locations) and is the costliest and longest phase to conduct. *Product implementation*, the final innovation stage, is measured as the number of drugs a firm has on the market that have completed clinical trials and been approved by the FDA to be sold in the United States. The data source for product development and product implementation is Recap. Each dependent variable is aggregated by year for each firm in the sample.

To model the impact of success at one stage on the other innovation stages, a dummy variable is included that indicates whether a firm has one or more products at each stage of innovation. Each of these independent variables is lagged one year. Specifically, the dummy variable indicating whether a firm has one or more products at the invention stage (lagged), *invention dummy*, is included in models predicting product invention, development, and implementation. The dummy variable indicating whether a firm has one or more products at the development stage (lagged), *development dummy*, is included in models predicting whether a firm has one or more product invention, development, and implementation. The dummy variable indicating whether a firm has one or more product invention, development, and implementation. The dummy variable indicating whether a firm has one or more product invention, development, and implementation stage (lagged), *implementation dummy*, is included in models predicting product invention, development, and implementation stage (lagged), *implementation dummy*, is included in models predicting product invention, development, and implementation.

Dummy variables are used rather than the original count variables (i.e. the number of products at the invention, development, and implementation stages), used as dependent variables in the statistical models, for theoretical and practical reasons. First, when one product inhabits any given stage, the firm develops capability in that area in which it is operating. Additional products, such as the fifth or tenth, are unlikely to generate much value added or additional expertise. Second, the distributions for the count variables are highly skewed. Transforming these variables into dummies addresses potential problems that may result in the analysis from including variables with highly skewed distributions.

The first set of control variables includes organizational characteristics. Firm age is the number of years since founding and is transformed (natural log) to account for skew. Return on assets proxies firm performance and is measured as net firm income divided by total firm assets. Data for this variable come from Standard & Poor's Compustat. An additional variable, the number of employees (natural log), was included in initial analyses as a proxy for firm size, but was dropped because of multicollinearity with firm age and R&D expenditures. (The correlations between the number of employees and firm age and R&D expenditures were 0.85 and 0.77, respectively.) Firm patent inventors is measured as the number of inventors listed on each firm's patents in a given year. Patent inventor data were obtained from the United States Patent and Trademark Office (USPTO). For \$US50, the USPTO provided a DVD-ROM via mail containing data on patents and patent inventors.<sup>6</sup> R&D expenditures is measured in millions of US dollars (natural log) (Compustat). Strategic alliance variables are also included. Different types of strategic alliances proxy complementary assets and shared expertise, and increase the likelihood of success as a product progresses through different stages. Exploration alliances are more likely to predict products in development, and exploitation alliances are likely to be associated with the number of products on the market (Rothaermel and Deeds, 2004).

*Exploration alliances* is measured as the number of firm alliances dedicated to drug research activities (natural log). Rothaermel and Deeds (2004) provide an example. The drug Intron A, which is used to treat chronic hepatitis and hairy-cell leukaemia, was developed by

<sup>&</sup>lt;sup>6</sup> More information about the DVD-ROM and purchasing it is available at www.uspto.gov/web/offices/ac/ido/ oeip/taf/reports.htm#cust\_xtract (see heading 'PTMT Custom Bibliographic Patent Data Extract DVD-ROM') (accessed May 2016).

Biogen, a leading biopharmaceutical firm, in collaboration with the University of Zurich as part of an exploration alliance. Once a drug is initially developed, firms enter into partnerships, exploitation alliances, to carry out the clinical trials, gain regulatory approval, and commercialize the drug. *Exploitation alliances* is the number of alliances focused on drug development in clinical trials, manufacturing and distribution, and marketing (natural log). Data for the alliance variables come from Recap. Since Recap lists the year in which the alliances were created but not terminated, the coding procedure employed by as Robinson and Stuart (2007) is employed, based on an assumption that alliances remain partners for five years: 'We allow alliances to remain as 'active' links for a duration of 5 years, meaning that we consider alliances to be in existence if they were established within 5 years of the current year' (Robinson and Stuart, 2007, p.255). *Acquisitions* is the number of firms acquired (logged). Acquiring other firms is an important strategy for biopharmaceutical companies for obtaining technical knowledge and/or drugs in development. Data on firm acquisitions come from Recap.

#### Estimation procedure

A negative binomial regression estimation procedure is used to model the association between innovation stages. A negative binomial regression model is appropriate because the dependent variables are counts, and the variance is greater than the mean for each variable. All models are clustered by firm to account for correlated errors caused by repeated observations for the same firms across years, and models also include dummy variables for each year (except one) to control for unobserved heterogeneity across time. The analyses are performed in Stata 14 (StataCorp, 2015).

## Interviews

Qualitative data supplement the statistical analyses below by illustrating some of the reasons activities at one stage may be linked with activities at alternative stages. Interviews with five key informants in biopharmaceutical firms were conducted in March and April 2010. The interview guide included questions about the employee's job characteristics, organizational culture, and their firm's activities across the stages of innovation. Institutional Review Board (IRB) approval was obtained before conducting the interviews. Of course, the limited number of informants is inadequate to constitute a qualitative study. The informants are in no way representative of the key decision makers or research and development staff in biopharmaceutical firms. Including results from the interviews is not intended to justify or be viewed as a significant methodological component of this study. They are included merely to provide some context and insight beyond the quantitative results into the social interactions and information sharing that promote product success across stages. The qualitative results clarify how feedback that takes place between stages benefits activities associated with differing stages of innovation.

The informants were selected through a nonrandom online search of biopharmaceutical firms that conducted clinical trials in the Washington, DC, metro area and who positively responded to my request for an interview. The DC area is the fourth largest site for biopharmaceutical companies in the world (behind the San Francisco Bay Area; Boston and Cambridge, Massachusetts; and San Diego, California).<sup>7</sup> Interviews were conducted with four members of management (i.e. one CEO and three vice presidents who oversaw clinical development) and one lab engineer. Each member of management holds a PhD in a science-related field, which is common in biopharmaceutical companies, and the lab engineer was working on a PhD at the time of the informants came from firms with fewer than 100 employees, one came from a firm with approximately 2,500 employees,

<sup>&</sup>lt;sup>7</sup> See www.genengnews.com/insight-and-intelligenceand153/top-10-u-s-biopharma-clusters/77900061/ (accessed May 2020).

and the other was from a large pharmaceutical firm with tens of thousands of employees. A lab engineer was interviewed in addition to executives because management decisions about which products to pursue in various stages of product development are likely to differ from the preferences of the research scientists and engineers, who have comparatively limited discretion about which products to pursue.

#### Results

#### **Regression models**

Table 1 reports summary statistics for the variables employed in the regression models. For the dummy variables, all of which are lagged one year, in any given year 38% of the firms have one or more products at the invention stage, 45% have one or more products at the development stage, and 27% have one or more products at the implementation stage. The strongest correlation is between R&D expenditures and firm age (0.653). To assess potential problems caused by multicollinearity associated with strongly correlated variables, variance inflation factors (VIFs) for the independent variables were estimated. The average VIF is 1.49. The maximum VIF of 2.22 for R&D expenditures is below the recommended cut-off point of 10.0 (Cohen *et al.*, 2003). I also estimated models without each of the strongly correlated variables (R&D expenditures and firm age) and the results for the remaining variables did not differ substantially from those reported below.

Table 2 reports estimated coefficients for the negative binomial models. The first set of research questions asks whether product invention positively influences development (Research Question 1) and whether product development is positively associated with implementation (Research Question 2). In Model 4, product invention is a positive and significant predictor of product development. This positive and significant result is spurious, however, and does not hold in Model 5, which includes control variables. Specifically, the statistically significant association disappears once R&D expenditures is included in the model (Model 5). Thus, R&D expenditures seems to substitute for product invention. So, the answer to Research Question 1, is no.

Parameter estimates from the regression models answer Research Question 2 by showing that a firm with products in development has a positive and significant effect on products implemented (Models 7 and 8). Regarding Research Question 3, there is a positive, significant effect for product implementation on product development (Models 4 and 5). While there is not a statistically significant negative effect for product implementation on invention as suggested in Research Question 4, the effect is non-significant (Models 1 and 2). Thus, firms with products in development have experience with administrative tasks that may benefit product implementation, and proficiency at the product implementation stage benefits product development as well. But, experience at these stages do not translate into success or failure at the product invention stage.

Finally, as stated above, it is expected that having products in multiple stages simultaneously will impact success at the other stages, though it is unclear precisely how it will impact the focal stage. Accordingly, interaction effects are positive and significant predictors across all of the stages. Having products in the development and implementation stages is significantly associated with having more products in the invention stage, as indicated by the significant effect for the interaction effect between product development and implementation on product invention (Model 3). Having products in the invention and implementation stages is significantly associated with having more products in the invention and implementation stages is significantly associated with having more products in the development stage (Model 6). Furthermore, engaging in product invention and development is beneficial for product implementation (Model 9). These results of these interaction terms provide statistical support for the statement made by one of the informants that firms often send information back and forth between the earliest and latest stages.

With respect to the control variables, the effects for R&D expenditures are statistically significant for two of the stages. R&D expenditures is positively associated with product invention as well as product development in Models 2 and 5, respectively, but these results do not hold for

	.10										1.000
	9.									1.000	0.477
	8.								1.000	0.380	0.307
	7.							1.000	0.184	0.300	0.236
	6.						1.000	0.535	0.225	0.293	0.223
	5.					1.000	0.163	0.312	0.120	0.136	0.092
	4.				1.000	0.256	0.430	0.653	0.127	0.277	0.125
	3.			1.000	0.308	0.163	0.198	0.279	0.130	0.418	0.153
	2.		1.000	0.252	0.276	0.044	0.179	0.182	0.193	0.375	0.161
	1.	1.000	0.125	0.083	0.211	0.102	0.320	0.323	0.228	0.115	0.081
tions	Std. Dev.				10.97	0.68	107.72	795.44	1.09	2.12	1.48
variate correla	Mean or %	0.38	0.42	0.27	10.14	-0.36	39.80	209.78	0.74	1.37	0.51
Table 1. Descriptive statistics and biv	Variable	1. Invention dummy (lagged)	2. Development dummy (lagged)	3. Implementation dummy (lagged)	4. Firm age	5. Return on assets (ROA)	6. Firm patent inventors	7. R&D expenditures	8. Exploration alliances	9. Exploitation alliances	10. Acquisitions

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<b>Table 2.</b> Unstandardized coeffic	ients for fixed-	year negative l	oinomial mode	els predicting su	uccess at each	stage of innova	ation, 1990–20	06 (robust star	idard errors)
	Inventio	n (Discovery pr	ojects)	Developmen	tt (Drugs in clin	iical trials)	Implementat	tion (Drugs on 1	the market)
Independent Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Invention dummy (lagged)	4.497***	4.142***	4.131***	$0.414^{***}$	0.058	-0.094	0.765***	$0.391^{**}$	-0.148
	(0.274)	(0.286)	(0.286)	(0.110)	(0.092)	(0.113)	(0.180)	(0.115)	(0.264)
Development dummy (lagged)	-0.080	-0.437	$-0.563^{*}$	2.399***	2.009***	2.020***	1.346***	$1.015^{***}$	0.874***
	(0.268)	(0.233)	(0.246)	(0.116)	(0.127)	(0.129)	(0.168)	(0.211)	(0.232)
Implementation dummy (lagged)	0.289	-0.173	-1.222*	0.629***	$0.229^{**}$	0.116	3.677***	3.222***	3.222***
	(0.284)	(0.223)	(0.507)	(0.107)	(0.082)	(0.09)	(0.166)	(0.158)	(0.158)
Development*implementation			$1.138^{*}$						
			(0.558)						
Invention*implementation						$0.341^{*}$			
						(0.149)			
Invention*development									$0.548^{*}$
									(0.278)
Controls									
Firm age (log)		-0.156	-0.125		-0.108	-0.099		-0.045	-0.040
		(0.204)	(0.202)		(0.062)	(0.062)		(0.128)	(0.128)
Return on assets (ROA)		-0.161	-0.159		-0.038	-0.030		$0.515^{**}$	$0.520^{**}$
		(0.128)	(0.128)		(0.026)	(0.028)		(0.183)	(0.184)
									(continued)

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(continued)

	Inventio	on (Discovery p	rojects)	Developme	nt (Drugs in cli	nical trials)	Implementa	tion (Drugs on	the market)
Independent Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Firm patent inventors (log)		0.073	0.071		0.045	0.041		0.003	0.005
		(0.045)	(0.045)		(0.023)	(0.023)		(0.025)	(0.026)
R&D expenditures (log)		$0.217^{**}$	$0.213^{**}$		$0.128^{***}$	$0.130^{***}$		060.0	0.085
		(0.082)	(0.082)		(0.031)	(0.031)		(0.055)	(0.055)
Exploration alliances (log)		0.189	0.195		$0.238^{**}$	0.231**		-0.157	-0.159
		(0.189)	(0.193)		(0.075)	(0.070)		(0.097)	(0.096)
Exploitation alliances (log)		0.204	0.155		$0.287^{***}$	0.282***		$0.308^{**}$	$0.308^{**}$
		(0.186)	(0.188)		(0.057)	(0.057)		(060.0)	(060.0)
Acquisitions (log)		-0.075	-0.074		$0.133^{*}$	$0.111^{*}$		0.318***	0.318***
		(0.180)	(0.180)		(0.059)	(0.056)		(0.086)	(0.085)
Year dummy variables									
		included	included		included	included		included	included
Constant	$-2.002^{***}$	-2.297***	$-2.181^{***}$	$-1.142^{***}$	$-1.232^{***}$	-1.205***	-4.125***	$-3.726^{***}$	-3.583***
	(0.323)	(0.443)	(0.443)	(0.112)	(0.163)	(0.162)	(0.219)	(0.401)	(0.412)
Firms	113	113	113	113	113	113	113	113	113
Observations	1295	1295	1295	1295	1295	1295	1295	1295	1295
Pseudo log likelihood	-1539.52	-1476.49	-1473.74	-2719.68	-2479.77	-2469.67	-922.17	-817.08	-816.45

Table 2. (continued)

"p < .05, "" p < .01, "" p < .001 (two-tailed tests)

product implementation in Model 8. These results are unsurprising since R&D expenditures provide resources devoted to earlier stage activities. The effect of exploration alliances has a positive and significant effect on development (Model 5), but surprisingly, not on invention (Model 2). It seems 'going it alone' without the aid of a strategic alliance partner is easier at the earliest stage, controlling for other factors. Exploitation alliances is a positive and significant predictor for product development and implementation (Models 5 and 8). As would be expected, exploitation alliances are more likely to benefit downstream activities. At the final stage, product implementation, the effect of return on assets (ROA) is positive and significant (Model 8), which may reflect some reverse causality. That is, having more drugs on the market would seem to improve financial performance and *vice versa*.

Taken together, the results from the quantitative and qualitative analyses highlight a couple of broad patterns that characterize links across stages of innovation. First, when control variables are not included in the models, the results show a positive, unidirectional relationship on outcomes at subsequent stages (i.e. activities at the product invention stage foster development (Model 4) and development promotes invention (Model 7)). In this way, some support exists for a sequentialist framework across stages that is implicit in the Stage-Gate and innovation value chain perspectives. Second, qualitative and quantitative results also support the relational view. This is the case between the later stages of innovation, product development and implementation, and is indicated by the positive and significant interaction effects. The feedback or synchrony that exists between the development and implementation stages, which are animated by complementary and administrative tasks, are not apparent for the independent effects of product development and implementation on invention.

# Interview results

Findings from interviews affirm that navigating the stages of innovation is indeed a relational enterprise that is based on prior experience and expectations about the future. The informants spoke often about how they considered activities at other stages to inform focal-stage activities and agreed that whether a new product becomes successful can be greatly aided by the scientific and administrative expertise gained from other stages. A comment from the vice president of a successful biopharmaceutical company describes the overall fluidity between the boundaries of innovation stages:

The lines between discovery, product development, and commercialization are dividing lines that are pretty grey because the later stages of activities are taking what they've learned and sending that information back to the early stages of discovery and development, including what's important in the market or a patient population in any particular therapeutic area we're working on. And then each group is also reaching back to know what's coming so that when it gets there, you're ready for it and you're not thinking about it now for the first time.

This informant's company makes decisions about which drugs to pursue by using criteria from later stages to evaluate early stage activities and *vice versa*. When her company considers a number of different antibodies as potential drug candidates, the development department evaluates the antibodies according to the firm's ability to manufacture them and put them into a stable form and whether the drug would need to be delivered in a particular way for a target population.

Each informant spoke of the importance of building on competencies from earlier stages in later stages. With respect to product invention in particular, the interviews support the view that product development is based on product discovery. Informants discussed both patenting and drug discovery when speaking about product invention. Though patenting is not the measure of product invention used here in the quantitative analysis, it is an often-used proxy for invention in the innovation literature (cf. Sorensen and Stuart, 2000). Informants from the smaller firms seemed to have

fewer financial resources at their disposal to devote to searching for novel alternatives compared with the larger firms and were more likely to emphasize the importance of building on core competencies at the discovery stage in subsequent product development. An executive in a small firm with limited resources stated that patenting provided his firm with a knowledge base on which drugs being developed in its clinical program were built. All of his firm's patents were issued to the cofounder, and whenever the firm decides to pursue a new drug in clinical trials, it builds on patents developed by the co-founder.

Perhaps as important as having products upstream in the innovation value chain for downstream success (e.g. product invention is important for product development) is having products downstream that provide experience and feedback for activities at earlier stages. Recall the informant who commented that her company made a concerted effort to use knowledge gained from later stages about the market or patient population to inform products at earlier stages. The CEO of another company commented that when deciding which products to develop, his firm looks for 'unmet medical needs [in the market].... How does your drug fit into the panoply of drugs? Figure out whether the product fits a niche; what we are doing is different and complementary. It's pretty straightforward.' The decision-making criteria are clear-cut because the drug development process is expensive, and the difference between firm success and failure can hinge on the market success of one product, especially for small companies. Another executive succinctly put her criteria for evaluating whether to develop a drug. She stated that the criteria are 'the size of the market of a potential drug' and 'the unmet medical need'. These criteria are revisited by the firm constantly throughout each stage of innovation when evaluating a particular drug and deciding among alternative candidate chemical compounds. Still, market considerations were not the only criteria for this successful firm. The same executive continued, 'And then once you've gotten over It's the market and an unmet medical need, then it's a matter of You've got the product that is going to be safe.'

Another executive interviewed oversees his company's clinical development programme and describes in detail how product development activities are influenced by marketing considerations. He remarked that members of his marketing team often provide valuable feedback by asking him to gather information that distinguishes one of their drugs in clinical trials from other drugs on the market.

Now the marketing team is going to tell me, I can sell your product if you give me these answers. ... [W]hen they go out and sell the drug, they have to be able to compete against [another] product and say we are better than this drug because I can demonstrate that through my clinical program. Now, if I can't measure that or figure out how to do that, the marketing team is going to come back to me and say, 'I don't care what you're doing; you can get all the approvals you want and you can spend 800 million dollars in the approval process, but in the end, because of what you're giving me, I can't compete against the competition. Or, I can't provide the information I know the doctors are going to be asking for.' So, marketing has an important say in the clinical development program because ultimately you want to be able to give them the answers you need to sell your product.

Responses from these informants not only illustrate fluidity between stages, they highlight expectations about subsequent stages as a primary consideration for activities at the focal stage. These considerations are no doubt present for the many firms engaged in product innovation. Many firms attempt to anticipate the market with products at all stages of innovation, but not all firms are proficient at incorporating knowledge about the market into product development.

#### **Discussion and conclusion**

Although the samples used in the quantitative and qualitative analysis are limited in size and scope (i.e. limited to one industry), the primary contribution of this paper includes taking a first step toward advancing a relational view of innovation that focuses on the links between stages of

innovation. Existing research identifies various innovation stages, but has yet to offer a systematic explanation of why activities at one stage affect activities at another stage. Applying the notion of temporality, and its impact on behaviour, advocated by the relational view to the setting of innovation suggests that the stages of innovation are fluid because feedback from activities at one stage influence simultaneous or subsequent activities and outcomes at other stages.

An especially novel finding from this paper is that feedback between stages does not necessarily need to precede a subsequent stage and reciprocity between stages may exist. Activities downstream in the innovation value chain, such as product implementation, may generate positive feedback for an earlier stage, product development. In the case of product development, results from regression models indicate that the firms included in the sample seem to be learning from experience with activities at the subsequent stage, product implementation. The findings also show that cumulative advantage appears to occur across the stages of innovation. This finding is illustrated in regression models indicating that firms with products in more than one alternative stage provide benefits for outcomes at the focal stage, in addition to interview data that suggest beneficial information flows between stages.

The innovation literature recognizes persistence between novel products in the firm by conceptualizing the conditions in which feedback, asynchronous or synchronous relationships, exists between stages. The present study adds nuance to this literature by unpacking the temporal complexities that exist for the stages of innovation across products. It is not just that novel products affect the production of subsequent novel products (the broad assertion of the persistence in innovation approach), but asynchronous and synchronous relationships may also exist between stages. Synchronies at one stage can create benefits that can be utilized at other stages. Or asynchronies may occur that exhaust resources to be used at other stages, thereby creating friction between stages.

The mechanisms through which information is most effectively transmitted between stages is unclear in my analysis because of the lack of data to examine the interpersonal relationships of personnel involved in innovation processes. The types of social ties and interactions undoubtedly matter. Yet the key independent variables used in this study are merely proxies for organizational learning that occurs through social interactions between organizational members. The key independent variables that establish statistical links between stages do not elucidate how these connections are created and constituted.

Of course, this limitation provides opportunities for additional research. Future research should examine how individuals collaborate to search for, decide to use, and transfer information from previous and subsequent stages. A related avenue for further research could examine cross-functional teams and how they are organized to help provide feedback about the criteria necessary to succeed on the market. For instance, product managers could create teams that oversee and integrate activities across stages for one particular product. This team would consist of members who have product-specific expertise in activities related to each stage of innovation: invention, development, and implementation. Or another type of team could focus on integrating efforts across all products in the firm's portfolio. Members of this team would have experience with multiple products, but expertise in the invention, development, or implementation stage.

Although this paper offers merely a starting point for developing a framework that addresses links between the stages of innovation, another weakness includes the limited number of stages and the scope of the antecedents of success examined. Rogers (2003) identifies five stages in organizational innovation including defining a problem that creates a need to innovate (agenda-setting) and finding and assessing how well a particular solution will address the problem (matching). Then, once the decision to adopt a solution has been made, the next stages consist of modifying the solution to fit the organizational structure and altering the organizational structure to accommodate the solution (redefining/restructuring), refining the solution and resolving misunderstandings to improve widespread use (clarifying), and incorporating the solution into the organization's structure (routinizing). Moreover, the antecedents of success across stages

examined in the present study are also limited. The TIS literature offers insight into the many actors and institutional arrangements beyond the boundaries of the firm that influence the success of a novel product. A more robust explanation of innovative success than the one offered here would build on the TIS framework to identify and systematically examine the intra-organizational and extra-organizational factors that affect success at each stage, as well as which factors affect success at multiple stages of innovation.

That we have much to learn from the past is a truism promulgated in management and history alike. Yet, it is equally important to remember that feedback provided by engaging in activities at subsequent stages can also inform products in current stages. This feedback becomes a possibility when the boundaries between the stages of innovation are permeable so that insights from alternative stages inform activities at the focal stage. Feedback from alternative stages may be provided by members of teams who work with products in different innovation stages and are allowed to share expertise in ways that help one another anticipate challenges that may arise in the future for products developed in the present. In this sense, and to state the conclusion more provocatively, the path to successful innovation involves not only learning from the past, but learning from the 'future' as well.

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