Strategic Management Journal
Strat. Mgmt. J., **36**: 709–727 (2015)
Published online EarlyView 5 March 2014 in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/smj.2240
Received 4 April 2013; *Final revision received 27 January 2014*

LIGHTING THE WAY OR STEALING THE SHINE? AN EXAMINATION OF THE DUALITY IN STAR SCIENTISTS' EFFECTS ON FIRM INNOVATIVE PERFORMANCE

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Do star employees enhance or constrain the innovative performance of an organization? Using data from 456 biotechnology firms between 1973 and 2003, we highlight the duality of the effects that stars have on firm performance. We show that while stars positively affect firms' productivity, their presence constrains the emergence of other innovative leaders in an organization. We find that firm productivity and innovative leadership among non-stars in a firm are greatest when a star has broad expertise and collaborates frequently. We offer cross-disciplinary insights into the role of human capital as a source of competitive advantage, suggesting that the value of human capital in a firm is contingent on the mutual dependence inherent in high-status employees' relationships with other individuals in a firm.

INTRODUCTION

A firm's success and viability are contingent on the quality of its human capital (Coff and Kryscynski, 2011; Paruchuri, 2010). Consequently, many organizations make significant investments in maintaining their star employees, who are regarded as highly productive and who have superior visibility in the external market (Groysberg, Lee, and Nanda, 2008; Oldroyd and Morris, 2012). In research environments, stars inventors are commonly believed to positively affect firms' innovative productivity, not only directly through their individual contributions, but also indirectly by providing knowledge spillovers that improve their colleagues' productivity (Zucker and Darby, 1997). The organizational resources and attention conferred to a star may, however, limit the opportunities of other, non-star, inventors to provide innovative leadership (i.e., to initiate and independently lead innovation). The development of other potential innovative leaders in an organization is particularly important as it causes a firm to be less dependent on a star for innovation and thus less vulnerable to disruption of its innovation activities in the face of star turnover (Coff, 1999).

Despite an increasing research focus on stars' positive effects on firm performance, the extant literature is silent on the potential for star inventors to have dual effects on organizations' innovative performance. Further, and more importantly, while research suggests that key employees may occupy different internal positions in a firm's workflow (Ibarra, 1993; Paruchuri, 2010), we know little about how the effects of stars vary based on these positions and on the social interdependencies associated with them. To delve into these

Keywords: star employee; expert power; human capital; resource-based view; innovative performance
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issues, we draw on two key concepts from resource dependence theory: power imbalance and mutual dependence (Casciaro and Piskorski, 2005; Emerson, 1962). From this perspective, we address two key questions concerning stars' effects on firm performance—namely, how does the presence of a star affect innovative productivity and leadership, and under what conditions do these effects vary?

First, we suggest that stars' discretion over the tacit knowledge underlying the generation of successful innovations and the tangible organizational resources funneled to support a star's research creates a power imbalance between stars and their colleagues. As a result, stars exert disproportionate influence over an organization's research direction and program, which in turn influences other scientists' opportunities for innovative productivity and leadership.

Second, we suggest that the relative balance in the mutual dependence (or bilateral dependencies) between a star and his colleagues may moderate stars' effects on colleagues' innovative performance (Casciaro and Piskorski, 2005), and we identify two key factors in determining this balance in knowledge-intensive firms: the star's collaborative strength in the firm and the breadth of the star's expertise. By fostering trust and tacit knowledge exchange, collaborative strength between a star and his colleagues creates greater balance in dependence. The breadth of a star's expertise increases the scope and number of colleagues over whom a star may exert influence, as well as the star's dependence on colleagues for support in the star's own research. Through these mechanisms, we contend that a star's collaborative strength and expertise breadth moderate a star's effects on colleagues' innovative productivity and leadership.

We develop a contingency model to examine the relationship between the presence of a star and the innovative productivity and innovative leadership in an organization, and to address the questions of how and under what conditions these effects vary. We test our predictions with a study of 456 dedicated U.S. biotechnology firms in the time period from 1973 to 2003.

Our study advances knowledge on the influence of stars on their firms' innovative performance in several ways. First, we transcend prior findings focusing on stars' positive influences through a knowledge spillover perspective by incorporating a resource dependence approach, which enables us to identify the dual influences that stars exert on firms' innovative performance. Although we replicate previous findings that stars benefit their organizations' productivity (Hess and Rothaermel, 2011; Rothaermel and Hess, 2007), we underscore that a star's presence also constrains the emergence of other innovative leaders in a firm. Second, we demonstrate that stars' effects on firms' innovative performance vary based not only on the type of performance outcome, but also on the relative balance in stars' relationships with their colleagues. By integrating human capital theory with the resource dependence literature, we offer insights for cross-disciplinary assessments of the role that high-status individuals play in the development of a firm's human capital and sustained competitive advantage.

THEORETICAL BACKGROUND

In knowledge-based industries, a firm's human capital provides the scientific foundation and creative imagination necessary to identify opportunities for knowledge to be combined and recombined (Tzabbar, Aharonson, and Amburgey, 2013). The knowledge-based view promotes a "democratic notion" of the firm in which employees undertake specialized activities in the innovation process and learn different things about the transformation of inputs into outputs (Spender, 1996). Knowledge is perceived as a "private good," which requires discretion in the sharing of employees' expertise and transformation of tacit knowledge in order for other employees to learn what an individual has discovered (Nonaka and Takeuchi, 1995).

Similar to the knowledge-based view, resource dependence theory recognizes that a key determinant of organizational behavior is the mutual dependence in social relationships, which is governed by individuals' discretion over their key resource—knowledge. The mutual dependence between two actors is influenced by the importance of the resource that each actor holds for the other actor's performance, the extent of each actor's discretion over the use of the resources desired by the other actor, and the extent to which the resource or an adequate substitute is available to each actor through alternative sources. Within a firm, when individuals or units hold discretion over resources that are critical to organizational functioning and no adequate substitute is readily available, these actors tend to have more influence (Pfeffer, 1981).

In knowledge-based industries, where specialized expertise is critical in the pursuit of organizational goals, differences in employees' human capital contribute to dispersion in power within a firm (Tzabbar, 2009). Thus, stars—identified as individuals who have demonstrated disproportionately high levels of performance and have superior visibility in the external market (Groysberg *et al.*, 2008)—enjoy power and social status based on the value, complexity, and uniqueness of their exceptional expertise (French and Raven, 1959). As a result, stars tend to assume central roles in a firm's workflow structure (Paruchuri, 2010) and control the flow of key resources within and between firm boundaries (Zucker, Darby, and Torero, 2002), creating an imbalance in the exchange relationships between stars and other organizational members. This imbalance is reinforced by stars' control over the use of their knowledge by others and by the prestige that makes stars desirable role models and partners in exchange (Thye, 2000). In combination, these factors make stars' superior expertise and positive influence on a firm's research program even more valuable and difficult to replace (Zucker, Darby, and Brewer, 1998).

Star inventors' expert status positions them to affect both the innovative productivity and innovative leadership in a firm. Innovative productivity reflects a firm's achievement of repeated innovative success and requires a firm to have the ability to access and effectively utilize the knowledge and tangible resources required for effective research in a defined domain (Nelson and Winter, 1982; Paruchuri, 2010). Innovative leadership is defined as the ability of a firm's members to initiate and lead innovation, and thus ultimately defines a firm's capacity to attain continuous innovative productivity (Dosi, 1982; Teece, Pisano, and Shuen, 1997).

In the case of innovative productivity, the incentive of a star to sustain his high-status position by maintaining high levels of innovative productivity is aligned with the firm's and colleagues' innovation goals. In particular, a star's investment in providing his colleagues with opportunities for innovative productivity may enhance the star's own productivity and prestige and contribute to organizational goals for innovative success at the same time. However, investing in colleagues' innovative leadership opportunities may not so closely align with a star's own goals. Specifically, advancing colleagues' innovative leadership requires a star to share tacit knowledge and resources to support colleagues' research initiatives (Zollo and Winter, 2002). Such investments may limit a star's ability to pursue his own research agenda and sustain his unique position as an innovative leader in the firm (Overbeck and Park, 2006). Thus, a star's presence may undermine colleagues' opportunities to emerge as innovative leaders.

Star inventors' desires to preserve their unique positions and firms' expectations for stars to lead research, however, are not always consistent with other demands and expectations that emerge in the context of a star's interdependencies within a firm (Astley and Sachdeva, 1984). As much as the firm and a star's colleagues depend on the star's expertise, the star is also dependent on the firm's willingness to provide tangible and intangible resources to support the star's work. Furthermore, to maintain their advantageous status, stars must achieve some minimum level of symmetry in their exchanges with colleagues, such that both they and their colleagues benefit from their interactions (Piskorski and Casciaro, 2006). Should a star fail to fulfill this expectation, his colleagues may respond by assigning the star lower status, demonstrating less openness to the star's influence (Willer, 2009), or reducing the extent to which they engage with the star in the future (Piskorski and Casciaro, 2006). Further, while it is within the firm's interest to support the star, the firm also has an incentive to limit its dependence on a star by developing the capabilities (e.g., innovative leadership) of other scientists in the firm, as the existence of other capable inventors improves the likelihood of continued success for the firm should the star depart (Coff, 1997; Tzabbar and Kehoe, 2014). Such mutual dependence defines the nature of exchange between the star and the firm. The incentive that stars have to preserve their own unique positions while fostering mutual benefits in their exchanges with colleagues explains the duality we expect to find in the effects that stars have on an organization's performance.

From this perspective, ultimately, the effect of a star's presence on innovative productivity and leadership in a firm will be determined by the extent to which the mutual dependence between a star and his colleagues in the firm is balanced, with more balanced relationships increasing the star's motivation to ensure that colleagues benefit from their exchange with the star. Two factors are likely to be particularly important in determining the relative balance in a star's relationships with his colleagues:

the star's collaborative strength in the firm and the breadth of the star's expertise. A star's collaborative strength in a knowledge-based context is reflected in the frequency of collaboration between a star and his colleagues and is likely to foster greater balance in the exchange relationship as it provides increased opportunities for other scientists to support the star's work, increases mutual trust, reduces opportunistic behavior, and thereby facilitates the transfer of the star's tacit knowledge. In turn, a star with high collaborative strength with colleagues is likely to feel less threatened by the potential reductions in the criticality of his expertise and by the emergence of potential substitution for his knowledge among other scientists in the firm. The breadth of a star's expertise defines the scope of the colleagues within the firm for whom the star's key resources (i.e., knowledge and guidance) are relevant, and thus the scope of the indirect influence the star may exert in the organization. At the same time, breadth in a star's expertise increases the star's dependence on his colleagues for support in research initiatives across a larger range of domains. Thus, we expect greater breadth in a star's expertise to be associated with increased balance in the star's mutual dependence with colleagues as well.

HYPOTHESES

Stars' effects on their firms' innovative performance

With respect to performance record, expertise, reputation, and network centrality, star scientists are positioned at the extremes of many status-oriented spectra. Their presence in an organization has a significant influence on a firm's innovative productivity both directly through their individual performance and indirectly through means that extend beyond the contributions they make in their individual work. In particular, a star's presence is likely to positively impact the quantity and quality of colleagues' research efforts, thereby improving a firm's productivity. Stars' deep knowledge enables them to identify the most promising research opportunities (Zucker *et al.*, 1998). As reputable experts and central players in the scientific community, stars have access to and discretion over expert knowledge, tangible resources, and influential actors in the external and internal environment (Liebeskind *et al.*, 1996; Zucker *et al.*, 1998), providing stars unique opportunities to continuously execute successful innovation, thereby contributing to their firms' innovative productivity.

Stars can have less direct effects on their organizations' productivity as well. As a result of the increased quantity and fruitfulness of innovative activities driven by star inventors, other scientists in the star's firm also enjoy more opportunities to pursue research. Since star inventors exert disproportionate control over a firm's research agenda, a star's presence tends to promote a well-defined and well-funded research program. Specifically, the presence of a star provides other scientists in a firm with improved access to tangible and intangible resources, offering these scientists better opportunities to identify, evaluate, and pursue various innovative activities relative to peers in firms that do not have such access (Paruchuri, 2010). Further, through vicarious learning and behavioral modeling, scientists working alongside a star may enact behavioral norms conducive to research productivity (Wood and Bandura, 1989). Consequently, a star's colleagues encounter less uncertainty and fewer hurdles associated with innovation, ultimately contributing to increased productivity for the organization as a whole (Zucker *et al.*, 1998). In contrast, employees without the example of a star face greater difficulties in achieving high levels of productivity based on fewer available opportunities and on the lack of a role model from whom to learn the most effective work practices for innovation (Burke, Fournier, and Prasad, 2007).

Nevertheless, the contributions of knowledge, resources, and guidance that stars make to a firm's research program do not come without costs. In particular, stars' central roles in a firm's workflow structure and control of key organizational resources cause the firm and its other (i.e., non-star) scientists to grow dependent on the star's expertise and innovative leadership (Paruchuri, 2010). As much of the firm's tangible resources and human resources are allocated to support the star's research program, other scientists are likely to have less time and fewer resources available to pursue their own research agendas (Huckman and Pisano, 2006), thus reducing their opportunities to assume leadership positions in the firm's innovative activities.

Further, stars and other scientists in a firm may have conflicting interests with respect to the emergence of non-star scientists as innovative leaders. In particular, a star may view the sharing of tangible resources and tacit knowledge to advance

DOI: 10.1002/smj

colleagues' innovative leadership opportunities as inconsistent with the star's goals of advancing his own research agenda and preserving his unique status as an innovative leader in the firm (Overbeck and Park, 2006). Thus, stars may be less eager to invest in colleagues' innovative leadership than they are in colleagues' productivity and thus may limit their sharing of knowledge and resources for this purpose.

In contrast, in a more symmetric social structure (e.g., when no star is present), resources are more evenly distributed. Symmetric social structures have also been demonstrated to encourage broader involvement, enhance knowledge sharing, and increase the willingness and opportunity of all individuals to take initiative in collective efforts (Bunderson, 2003a, 2003b; Edmondson, 2002). As a result, in such contexts, a larger number of scientists are likely to assume innovative leadership in the firm's research efforts. Accordingly, we hypothesize:

Hypothesis 1a: The presence of a star increases a firm's innovative productivity.

Hypothesis 1b: The presence of a star decreases innovative leadership among a firm's non-star scientists.

The roles of the breadth of a star's expertise and star's collaborative strength

However, as innovation involves behavioral interdependencies, the nature of a star's effects on colleagues' innovative productivity and leadership is likely to vary with the extent to which the star's mutual dependence with other scientists is balanced. Specifically, we consider how stars' effects on their firms' productivity and innovative leadership vary with the degree to which a star's expertise spans a broad range of technologies and with the collaborative strength reflected in the star's co-invention with his colleagues in the firm.

The breadth of a star's expertise

The breadth of a star's expertise reflects the range of technological domains across which the star pursues research and can thus provide relevant, timely knowledge and access to opportunities for a firm. Therefore, the breadth of a star's expertise reflects both the scope of a star's expert power, as well as the range of technological domains across which a star may require support in innovative initiatives, suggesting important implications for the interdependencies between a star and the other scientists in a firm.

Relative to stars with narrow expertise, stars with broader expertise are likely to enjoy greater internal prominence and centrality. This centrality provides a star with opportunities to provide knowledge and research guidance relevant to more colleagues in the organization. This broader reach of the star's guidance increases the number of fruitful research opportunities and the likelihood of success in innovation for the organization as a whole. In particular, broader expertise enables a star to be involved in directing more varied research initiatives and to identify more unique knowledge recombination opportunities throughout an organization. The knowledge held by a star with broader expertise is also likely to be relevant to a larger pool of colleagues in the star's firm. This expertise reduces uncertainty and increases the likelihood of success associated with the research initiatives of a larger portion of the firm's human capital. Increased prominence also enhances the desirability of the star as a role model in the firm (Nerkar and Paruchuri, 2005). This position allows the star to indirectly shape the attitudes, norms, and behaviors of a larger portion of the firm's workforce more easily (Wood and Bandura, 1989), thereby facilitating work patterns conducive to greater productivity of the firm as a whole.

However, direct involvement in and control over multiple innovative projects may strain a star's cognitive capacity and thus threaten the star's ability to effectively oversee the successful completion of many varied research initiatives. In particular, broader involvement in multiple domains of research within a firm requires greater coordination, communication, and control, representing increased draws on the star's time and attention. Given individuals' (including stars') finite cognitive capacities, at a certain point, constant information flows to and from a star may cause the star to experience social and informational overload (Schroder, Driver, and Streufert, 1967). Such overload may hinder the star's ability to effectively communicate his knowledge or guidance to colleagues (Oldroyd and Morris, 2012) and obviate any potential benefits of additional breadth in the star's expertise. Thus, at a certain point, the positive effect of additional

DOI: 10.1002/smj

breadth in a star's expertise on productivity is likely to diminish.

Empirical evidence lends support to this argument as well, with previous research demonstrating that information overload reduces employees' motivation to share information (Kirsh, 2001) and, in turn, hampers learning outcomes (Schilling *et al.*, 2003). For this reason, we predict a nonlinear relationship between the breadth of a star's expertise and a firm's innovative productivity. Specifically, we argue that at low to moderate levels, increased breadth in a star's expertise will improve a firm's overall innovative productivity. At very high levels, however, we expect further increases in the breadth of a star's expertise to hinder the star's ability to help other scientists in their work, suggesting a limit to the positive relationship between the breadth of a star's expertise and firm-level productivity. Accordingly, we predict:

> *Hypothesis 2a: There is a diminishing positive relationship between the breadth of a star's expertise and a firm's innovative productivity. At low and moderate levels of breadth of a star's expertise, the firm's innovative productivity increases, but at higher levels of breadth of expertise, this positive effect weakens.*

The breadth of a star's expertise also has implications for the degree to which the mutual dependence between the star and his colleagues is balanced. When a star draws his status from expert knowledge across a broad range of technologies, we suggest that more balanced power dynamics may emerge in the star's relationships with his colleagues.

To prevent knowledge and social overload (Henderson and Cockburn, 1994), and in order to remain productive, stars with broad expertise are more likely to seek out and rely on the input and leadership of colleagues with specialized expertise in relevant domains. The resulting reciprocal exchange of knowledge is likely to create a balanced pattern of mutual dependence between these stars and their colleagues (Casciaro and Piskorski, 2005). Furthermore, for stars with broad expertise, the emergence of other potential innovative leaders poses less of a threat to the star's unique position in the organization, as the star's centrality to the firm's innovative activities is rooted both in his expertise across a plethora of technologies and in his ability to bridge scientists and knowledge gaps across many areas. As a result, stars with very broad expertise may develop more balanced patterns of intellectual exchange with their colleagues (Flynn, 2003), resulting in an increased willingness by (and perhaps necessity for) the star to relinquish control and invest time in sharing the tangible and intangible resources required for colleagues to assume innovative leadership (Van der Vegt, Bunderson, and Oosterhof, 2006).

In contrast, stars with narrow and moderate breadth in their expertise are likely to be less dependent on other scientists' contributions and thus may be less likely to maintain balanced intellectual exchanges with their colleagues. In particular, such stars may be better able to manage all or most research initiatives in the domains of their expertise (as the number of domains is limited) and may thus leave fewer opportunities open for colleagues' innovative leadership in these or other domains. Furthermore, when a star draws his status from expert power rooted in just one or a few knowledge domains, the star's "expertness" is vulnerable to redundancy when other scientists in the firm emerge and prove capable of leading research. Therefore, such stars may be more likely to assume a directive and protective stance in their exchange (Casciaro and Piskorski, 2005), limiting the sharing of tacit knowledge that may enhance the innovative leadership opportunities of other scientists in the organization.

Accordingly, we expect a U-shaped relationship between the breadth of a star's expertise and innovative leadership in a firm—with innovative leadership decreasing at low to moderate levels of breadth in a star's expertise and increasing at high levels of breadth in a star's expertise.

> *Hypothesis 2b: There is a U-shaped relationship between the breadth of a star's expertise and innovative leadership among a firm's non-star scientists. At low and moderate levels of breadth of expertise, the relationship is negative, but at higher levels of breadth, the relationship becomes positive.*

The extent of a star's collaborative strength

A star's collaborative strength, as reflected in the frequency and intensity of the star's collaboration with other scientists in the firm, is likely to influence the balance in the star's relationships with colleagues. In particular, stars who develop strong ties with their colleagues become more interdependent and thus engage in more balanced exchanges with their peers (Casciaro and Piskorski, 2005). As a result, stars with high collaborative strength are likely to be more willing to share knowledge and resources to support colleagues' research initiatives (Collins and Smith, 2006; Reagans and McEvily, 2003). On this basis, we suggest that a star's collaborative strength increases the abilities, motivation, and opportunities of both the star and his colleagues for high levels of innovative productivity.

Repeated collaboration between a star and his colleagues facilitates efficiency and effectiveness in knowledge transfer. When a star collaborates frequently, the star and his colleagues develop relationship-specific heuristics, a shared language and understanding, and common mental models (Kogut and Zander, 1992), reducing coordination costs in current and future joint innovative efforts (Vera and Crossan, 2005). More importantly, frequent collaboration weakens the prominence of social boundaries, making communication between a star and his colleagues more symmetrical (Harrison *et al.*, 2003).

Relative to stars who are weakly connected in a firm, stars with high collaborative strength are more central in their firm's work flow (Paruchuri, 2010), enabling them to act as bridging ties between various knowledge bases within the firm. By bridging internal structural holes, collaborative stars can better identify unique knowledge recombination opportunities and leverage the knowledge of local experts to capitalize on these opportunities for increased productivity for themselves and their colleagues (Hansen, 1999). Further, strong relationships increase a star's desirability as a role model, causing more colleagues to emulate the behaviors of these stars, which are conducive to innovative success (Wood and Bandura, 1989).

Thus, we argue that, relative to stars with low collaborative strength, stars that collaborate extensively increase the firm's collective opportunities for innovative productivity.

Hypothesis 3a: A star's collaborative strength increases a firm's innovative productivity.

Given that innovative leadership capabilities are rooted in individuals' tacit knowledge, which is best acquired through learning-by-doing (Polanyi, 1966), repeated collaboration is the best means by which colleagues can gain a deep understanding of the innovation process under a star's guidance. Collaboration facilitates the transfer of tacit knowledge, as familiarity in relationships reduces the risk of opportunistic behavior, increasing the source's and recipient's willingness to share and accept knowledge (Reagans and McEvily, 2003) and thereby fostering more balanced exchange (Granovetter, 1982; Williamson, 1991). Familiarity is further likely to buttress a star's belief that his colleagues' behaviors are rooted in fairness and increase the star's concern for colleagues' development and success (Van der Vegt *et al.*, 2009) and thus the star's willingness to share his tacit knowledge to facilitate colleagues' understanding of the innovation process (McEvily, Perrone, and Zaheer, 2003).

As familiarity increases balanced exchange, stars whose exchanges with colleagues are characterized by high collaborative strength are more likely to adopt an encouraging and participatory interaction style, because they recognize the importance of helping their colleagues develop deeper innovative capabilities (Nembhard and Edmondson, 2006). Consequently, such stars may be willing to increase the time and effort they invest in resolving transfer-related challenges (Szulanski, 2000) and in supporting colleagues' innovative initiatives more broadly (Van der Vegt *et al.*, 2009). In contrast, stars who collaborate less frequently with their colleagues may be more focused on furthering their own research agendas and less willing to invest time and effort in their colleagues' intellectual development. Accordingly, we argue that:

Hypothesis 3b: A star's collaborative strength increases innovative leadership among a firm's non-star scientists.

The joint effect of the extent of a star's collaborative strength and the breadth of a star's expertise on a firm's innovative performance

Implicit in the arguments above is that stars vary both in their collaborative strength and in the breadth of their expertise. Accordingly, stars' effects on colleagues' performance may vary, both between stars with narrow and broad expertise, and within each of these groups, based on the degree to which a star collaborates with colleagues.

When a star has broad expertise and high collaborative strength, the star may exert influence over a larger range and number of colleagues with

DOI: 10.1002/smj

decreased costs of communication and coordination based on increased familiarity and greater efficiency of exchange (Espinosa *et al.*, 2007). As a result, at high levels of breadth in a star's expertise, extensive collaboration by the star may mitigate the tapering off of the positive effect that the star's breadth of expertise has on a firm's innovative productivity by enabling colleagues to share some of the information processing burden that may otherwise strain the star's cognitive capacity. In this way, such stars may be able to leverage their mutual dependence with colleagues to benefit both the star's and his colleagues' innovative productivity simultaneously.

In contrast, when a star has low levels of collaborative strength with colleagues, the potential benefits associated with the star's broad knowledge may be limited by a lack of exchange opportunities and shared communication capabilities between the star and other scientists in the organization. This constraint necessarily reduces the balance in the mutual dependence between the star and other scientists, as it leaves such stars without the option to delegate information processing tasks to colleagues, thus providing fewer colleagues the opportunity to gain the knowledge and experience necessary to manage such tasks effectively. Furthermore, such stars are likely to be left to handle more information flows and requests on their own, increasing the likelihood of information overload. As a result, the increased breadth in the knowledge and resources the star brings to the organization may have a less positive effect on the firm's productivity. Accordingly, we expect that collaboration by a star will strengthen the positive effect of the breadth of a star's expertise on a firm's innovative productivity.

Hypothesis 4a: A star's collaborative strength moderates the relationship between the breadth of a star's expertise and a firm's innovative productivity, such that high collaborative strength increases the positive effect of the star's breadth of expertise on the firm's innovative productivity.

Similarly, we expect a star's collaborative strength to favorably influence the relationship between breadth in a star's expertise and innovative leadership in an organization. Specifically, we predicted a U-shaped relationship between the breadth of a star's expertise and innovative leadership. However, given that collaborative strength fosters familiarity and trust and contributes to a star's interdependence with other scientists in a firm, stars with narrow expertise who collaborate frequently may adopt a more balanced pattern of exchange with colleagues and thus engage in less turf protection and increased knowledge sharing to promote the innovative leadership opportunities of others. Relative to very collaborative stars, less collaborative stars with narrow expertise may be less embedded in their social networks, demonstrate less balanced mutual dependence with colleagues, and thus be more concerned about colleagues' potential opportunistic behavior. Such fears may intensify these stars' turf protection activities, such that they limit their sharing of tacit knowledge and innovative leadership opportunities with others.

For stars with broad expertise, collaborative strength increases a star's mutual dependence with colleagues. Specifically, under such conditions stars are likely to depend more heavily on other scientists' contributions in order to remain productive across their multiple research areas. Such stars may be especially inclined to view their sharing of expertise and leadership opportunities as necessary to maintaining balanced exchanges with their colleagues (Van der Vegt *et al.*, 2006). In contrast, stars with broad expertise who seldom collaborate may be less concerned with sharing knowledge to maintain balanced exchanges with other scientists.

Hypothesis 4b: A star's collaborative strength moderates the relationship between the breadth of a star's expertise and a firm's innovative leadership, such that high collaborative strength reduces the negative effect of low breadth of expertise on innovative leadership. In contrast, when the star has an extensive breadth of expertise, high collaboration increases the positive effect of breadth of expertise on innovative leadership.

DATA AND METHODS

Research setting

We tested our hypotheses using data from the field of biotechnology, which exemplifies a knowledge-intensive, dynamic setting in which innovative productivity and leadership are reflected in scientists' patenting activities. The need for biotechnology firms to develop creative solutions to complex problems forces research directors to be

DOI: 10.1002/smj

very dependent on the unique knowledge, skills, and backgrounds of their R&D members, allowing various individuals to assume leadership roles (Tzabbar, McMahon, and Vestal, forth coming). Furthermore, dedicated biotechnology firms typically have one R&D unit that is responsible for all innovations. These factors improve our ability to examine the direct effect of a star scientist on his colleagues and point to the appropriateness and importance of this context in testing our theoretical model.

We obtained data from a population of small, dedicated, and independent U.S. biotechnology firms founded between 1973 (the year of the Cohen-Boyer breakthrough involving recombinant DNA, often called the birth of modern biotechnology) and 2003. We identified firms using BioScan, the most comprehensive historical list of U.S. biotechnology firms. We cross-checked this information with the U.S. Companies Database (BioWorld), compiled by the North Carolina Biotechnology Center. We excluded all firms that were founded before 1973 or that were not independent entities (e.g., subsidiaries). The final sample consists of 456 dedicated U.S. biotechnology firms. We then compiled the life histories of all of these firms during the specified period and constructed a data set of all of the patented innovations generated by these firms. Finally, we identified all of the scientists involved in each patented innovation.

Dependent variables

The focal outcomes in this study are a firm's innovative productivity and innovative leadership. Following prior research (Ahuja and Katila, 2001), we used successful patenting as an indication of a firm's innovative productivity. We weighted patents by citations received in the five years after issuance to account for variance in patents' value (Sampson, 2007).

Innovative leadership reflects the ability of a firm's (non-star) scientists to initiate and lead research from innovation to patenting. We operationalized innovative leadership as:

$$\textit{Innovative leadership} = \sum i_j \times \left(\frac{n}{n-1}\right)$$

where i_j represents the number of non-star inventors who applied for patents on which a star scientist was not a co-inventor. We corrected for the possibility that the number of inventors might bias the measure. Consistent with our theory, our focus was on identifying the number of unique inventors who patented without a star and who had thus demonstrated innovative leadership, rather than the number of patents applied for without a star. This approach also enabled us to cleanly separate the measure from increases in innovative productivity associated with the presence of a star while accounting for the number of inventors in a firm. Hence, if non-star inventor *i* applied for three patents without a star and non-star inventor *j* applied for two patents without a star, we assessed their collective innovative leadership with a score of 2 rather than 5.

Independent variables

Firms with stars

To test our first two hypotheses, we distinguished between firms employing at least one star inventor and those with no star inventors. We followed previous research examining the biotechnology industry in identifying stars based on the quantity and impact of their cumulative research (Zucker and Darby, 2001). Specifically, to identify star scientists, we used the following formula:

$$\begin{aligned} &\textit{InvPerformance} \\ &= \left[\left(\frac{\textit{InvPat}_{it}}{\textit{IndTenure}_{it}}\right) \times \textit{AveForwardCite}_{it}\right] \end{aligned}$$

where $\textit{InvPat}_{it}$ represents the number of patents for which scientist *i* applied by year *t*. We divided this number by scientist *i*'s industry tenure as of year *t*, represented by the number of years since the scientist's first patent application. Given that forward citations in patents provide the best proxy for a patent's impact, we multiplied our calculations by the average forward citations of scientist *i*'s patents received by year *t*. Finally, we compared each inventor's productivity score at time *t* with the industry average.

A scientist whose productivity score is at least two standard deviations above the average of all inventors in our sample is defined as a star. We allowed for non-star scientists to become star scientists over time by updating scientists' scores annually. We identified 531 star scientists during the study period (about 7% of the scientists in our sample) who were employed by 155 firms. Accordingly, we followed the standard procedure and operationalized the star firm as a dummy variable, where

DOI: 10.1002/smj

1 indicates that a firm employs at least one star scientist.

Breadth of a star's expertise

In the biotechnology context, expertise is reflected in the breadth and depth of technological field in which a scientist patents. Accordingly, we assessed a star scientist's technological portfolio using all patent applications with which the star was involved. We conceptualized breadth of star expertise as the diversification in technological classes associated with a star's patents. Using Tzabbar's (2009) 22 technological fields, we indexed each field by $j = 1, \ \ldots, 22$, so that the N_i patents that scientist i had at time t could each be assigned a technological field. We let N_{ij} denote the number of patents the ith scientist holds in category j. Subtracting this value from 1, the breadth of expertise variable is:

$$\textit{Breadth of Star Expertise} = \left[1 - \sum_{j=1}^{22}\left(\frac{N_{ij}}{N_i}\right)^2\right]$$

We then followed Hall (2002) and used a nonbiased Herfindahl index for citations.

As some firms have more than one star scientist, we examined the effect of the breadth of expertise of the star with the highest level of expertise breadth.

Star's collaborative strength

Consistent with previous research, we examined the breadth and frequency of stars' co-inventions with colleagues to capture star-colleague collaboration (Uzzi, 1996). Specifically, we computed a star's collaborative strength as the average level of co-invention frequency between star and non-star scientists in firm s,

$$\text{Star collaborative strength} = \frac{\sum_{i=1}^{N_s}\sum_{j=1}^{N_s}\frac{z_{ijs}}{\max\left(z_{ijs}\right)}, j \neq i}{N_s\left(N_s - 1\right)}$$

where z_{ijs} (ϵ {0,1,2,3,4}) is the frequency with which star scientist i co-invents with team members j, max (z_{ijs}) is the largest possible number of collaboration ties that star scientist i could have within the firm, and N_s is the number of members in firm s. Collaborative strength varies from 0 (no co-invention) to 1, which would imply a complete network containing all possible ties among incumbent scientists.

To test Hypotheses 4a and b, we interacted collaborative strength with the breadth of a star's expertise. To facilitate the interpretation of our results, we mean centered the moderating variable terms and entered their main effects into the model.

Controls

Firm controls

To account for potential differences in the availability of research funds, we controlled for whether firms were publicly traded and for venture capital raised. We also controlled for firm size (i.e., the number of employees in a firm) as reported in BioScan and for firm age as the number of years since incorporation. For firms that patented prior to incorporation, we used the number of years since their first patent application as firm age.

Other sources of knowledge flow

To account for other knowledge flows that were not included in our theoretical model, we controlled for recruitment events (coded to equal 1 if such an event occurred in the previous three years, and 0 otherwise), geographic dispersion of R&D members (computed using an inverted Herfindahl index to assess geographic dispersion based on R&D member locations obtained from our patent data), and number of prior R&D alliances.

Further, to capture other potential influences on a firm's innovation processes, we controlled for firms' technological breadth (using a Blau index to capture diversity in the areas across which a firm has patented (Tzabbar, 2009)) and CEO succession (which we coded based on whether a firm appointed a CEO who was not previously part of the firm's top management team using data from BioScan reports about key personnel, hiring announcements in LexisNexis, and firm contacts). Following prior research (Shen and Cannella, 2002), we used a three-year lagged measure to allow for sufficient time for new CEOs to exert their influences in a firm.

Research design

Testing our model required an analysis of two different firm samples. Specifically, to test our first two hypotheses, we compared the innovative productivity and innovative leadership of star and non-star

Table 1. Means, standard deviations, and correlations

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Innovative productivity	0.21	0.32													
2 Innovative leadership	0.31	0.43	−0.13												
3 Breadth of star's expertise	0.04	0.11	0.29	0.42											
4 Star collaborative strength	0.38	1.50	0.46	0.36	0.25										
5 Star firm	0.16	0.37	0.47	−0.49	0.24	0.33									
6 Public firm	0.35	0.48	0.13	0.06	0.20	0.08	0.17								
7 Firm size (log)	2.70	1.37	0.27	0.06	0.19	0.33	0.05	0.20							
8 Firm age (log)	1.89	0.82	0.14	0.22	0.22	0.20	0.26	0.36	0.16						
9 Venture capital (log)	5.75	2.27	0.10	0.13	0.20	0.07	0.08	0.09	−0.21	0.11					
10 Scientist recruitment event	0.17	0.38	0.09	0.06	0.13	0.15	0.09	0.01	−0.15	0.08	0.35				
11 Geographic dispersion	0.45	0.71	−0.11	0.21	0.00	−0.01	−0.29	−0.26	−0.11	−0.31	−0.03	0.02			
12 Prior R&D alliance	2.12	6.49	0.07	0.08	0.15	0.22	0.18	0.39	0.21	0.53	−0.01	0.00	−0.24		
13 CEO succession	0.00	0.01	0.03	0.03	0.00	0.07	0.02	0.00	0.03	−0.01	0.01	−0.01	0.00	−0.00	
14 Technological breadth	0.25	0.32	0.06	0.18	0.17	0.15	0.16	0.17	0.08	0.37	0.01	0.05	−0.36	0.23	0.01

firms. The remaining hypotheses are focused on the characteristics of stars and thus required us to restrict our analyses to the 155 firms that employed at least one star inventor.

Analysis

The cross-sectional (across firms) and time-series (over years) data suggest the appropriateness of panel data methodology. We used generalized least squares (GLS) regression to test our hypotheses. One challenge in testing our model is that differences between firms with and without star scientists could be attributed to initial differences in the quality of human capital between these firms. We addressed this issue in a few ways. First, we accounted for some of these differences by using a fixed effects model. Our data encompassed virtually the entire population of dedicated and independent U.S. biotechnology firms, rather than random draws from a population, obviating a key assumption of random effects (Wooldridge, 2003). A Hausman test also indicated significant ($p < 0.01$) systematic differences in the coefficients of the random effects versus fixed effects models, suggesting that the fixed effects models were more appropriate.

Second, we corrected for potential endogeneity by using a two-stage Heckman selection procedure (Heckman, 1979). In the first stage, we generated an inverse Mills ratio, which accounts for the likelihood of recruiting a star inventor. Given that firms with high levels of innovative performance and quality human capital can attract star scientists, we examined the effect of *prior firm patents* and *number of star inventors* on star recruitment. We then included this Mills ratio as a coefficient in the second stage where we examined the effects of our theoretical variables.

Descriptive statistics

In Table 1, we present the means, standard deviations, and correlations among the independent and control variables. Variance inflation factors (VIFs) derived from an ordinary least squares regression and modest correlations between the independent variables suggested that multicollinearity problems were unlikely (highest VIF = 2.67). We took additional steps to avoid problems with multicollinearity by centering the variables used to test the predicted interactions. In addition to mean centering the interaction terms, we tested the significance of groups of variables, compared against a series model, and examined the coefficients' standard errors for inflation to ensure that multicollinearity was not causing less precise parameter estimates (Kmenta, 1986).

RESULTS

The effect of stars on their firms' innovative productivity and innovative leadership

Innovative productivity

In Table 2, we detail the results pertaining to the main effects of employing a star on a firm's innovative productivity (Hypothesis 1a). In Models 1 and 2, we focused on all of the patents that firm *i*

DOI: 10.1002/smj

Table 2. GLS regression analysis for the effect of a star on a firm's innovative productivity and leadership

	Productivity including star patents		Productivity excluding star patents		Innovative leadership	
Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Star firm (Hypotheses 1a and b)		0.71***		0.22***		−1.41***
		(0.06)		(0.03)		(0.12)
Public firm	0.09**	0.08**	0.08**	0.08**	0.01	0.01
	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
Firm size (log)	0.19***	0.16***	0.13***	0.13***	0.03*	0.02*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.00)	(0.00)
Firm age (log)	0.17***	0.17***	0.15***	0.14***	0.01	0.01
	(0.03)	(0.03)	(0.03)	(0.03)	(0.00)	(0.00)
Venture capital (log)	0.14***	0.14***	0.09***	0.09***	0.01***	0.01***
	(0.02)	(0.01)	(0.02)	(0.01)	(0.00)	(0.00)
Scientist recruitment event	0.06**	0.07**	0.08*	0.08*	−0.03***	−0.03***
	(0.01)	(0.01)	(0.02)	(0.02)	(0.00)	(0.00)
Geographic dispersion	−0.43***	−0.41***	−0.41***	−0.41***	0.09***	0.08***
	(0.09)	(0.09)	(0.09)	(0.09)	(0.01)	(0.01)
Prior R&D alliance	0.03*	0.03*	0.02*	0.02*	−0.03**	−0.02**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)
CEO succession	0.05	0.04	0.05	0.04	0.02*	0.02*
	(0.16)	(0.15)	(0.16)	(0.15)	(0.00)	(0.00)
Technological breadth	1.09**	1.09***	0.98**	0.98***	0.48***	0.48***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.08)	(0.08)
Mills ratio: likelihood of recruiting star inventor	0.13***	0.13***	0.13***	0.14***	−0.06***	−0.05***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Constant	0.90	0.89	1.57	1.57	−0.20	−0.20
	(0.15)	(0.15)	(0.15)	(0.15)	(0.02)	(0.02)
R^2	0.14	0.21	0.13	0.18	0.24	0.29
Wald χ^2	1920.12	2229.73	2090.81	2309.91	1498.08	1601.41

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

applied for in year t. Model 2 in Table 2 provides a test of Hypothesis 1a, which predicted that the presence of a star increases a firm's innovative productivity. As expected, the presence of a star relates positively and significantly ($\beta = 0.71$; $p < 0.01$) to a firm's productivity. On average, the innovative productivity of firms with a star scientist is 71 percent higher than that of firms with no star. To further estimate the indirect effect of stars and to evaluate the extent to which increased productivity is explained by stars' own innovative productivity, we excluded patents in which the star was a co-inventor from Models 3 and 4. As shown in Model 4, the presence of star scientists relates positively and significantly ($\beta = 0.22$; $p < 0.01$) to a firm's productivity, reflecting a 22 percent increase in innovative productivity relative to firms with no star.

Innovative leadership

We tested Hypothesis 1b in Models 5 and 6 in Table 2. Using Model 6, we tested Hypothesis 1b, which predicted that the presence of a star reduces innovative leadership in a firm. As expected, the presence of a star relates negatively and significantly ($\beta = -1.41$; $p < 0.01$) to innovative leadership in an organization. On average, innovative leadership in firms with a star is 141 percent lower than in firms with no star inventor.

Roles of breadth of a star's expertise and degree of a star's collaborative strength

To determine whether the effect that stars have on their firms' innovative performance varies according to a star's collaborative strength and breadth of expertise, we focused our next analyses on the 155 firms in our sample that employed star scientists during the study period.

Firm's innovative productivity

Models 1 and 2 in Table 3 illustrate the effects of the breadth of a star's expertise and collaborative

Table 3. GLS regression analysis for the joint effect of the breadth of a star's expertise and collaborative strength on a firm's innovative productivity and leadership[a]

Variable	Innovative productivity		Innovative leadership	
	Model 1	Model 2	Model 3	Model 4
Breadth of star's expertise (Hypothesis 2a)		3.21***		2.38***
		(0.27)		(0.11)
Breadth of star's expertise^2 (Hypothesis 2a)		−4.85***		1.06***
		(0.39)		(0.16)
Star collaborative strength (Hypothesis 3a)		0.83***		0.57***
		(0.13)		(0.07)
Breadth of star's expertise × collaborative strength (Hypothesis 4a)		0.68***		0.27***
		(0.21)		(0.05)
Breadth of star's expertise × collaborative strength^2 (Hypothesis 4a)		−1.53***		−1.89***
		(0.34)		(0.09)
Public firm	0.09 *	0.07	0.01	0.02***
	(0.03)	(0.04)	(0.01)	(0.00)
Firm size (log)	0.19***	0.26***	0.03 *	0.10***
	(0.02)	(0.03)	(0.00)	(0.00)
Firm age (log)	0.17***	0.15***	0.01	0.02
	(0.03)	(0.03)	(0.00)	(0.03)
Venture capital (log)	0.14***	0.18***	0.01***	0.01**
	(0.02)	(0.01)	(0.00)	(0.00)
Scientist recruitment event	0.06**	0.08**	−0.03***	−0.01***
	(0.01)	(0.01)	(0.00)	(0.00)
Geographic dispersion	−0.43***	−0.32***	0.09***	0.11***
	(0.09)	(0.09)	(0.01)	(0.01)
Prior R&D alliance	0.03*	0.08*	−0.03**	−0.01***
	(0.01)	(0.01)	(0.00)	(0.00)
CEO succession	0.05	0.01	0.02*	0.02**
	(0.16)	(0.15)	(0.00)	(0.01)
Technological breadth	1.09**	0.91***	0.48***	0.45***
	(0.11)	(0.12)	(0.08)	(0.01)
Mills ratio: likelihood of recruiting star inventor	0.13***	0.14**	−0.06***	−0.09**
	(0.01)	(0.01)	(0.01)	(0.01)
Constant	0.90	0.85	−0.20	−0.20
	(0.15)	(0.14)	(0.02)	(0.02)
R^2	0.14	0.38	0.24	0.41
Wald χ^2	1920.12	2681.06	1498.08	2387.73

[a] Nested models are robust.
†$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

strength on a firm's innovative productivity. As indicated in Model 2 and consistent with Hypothesis 2a, our results demonstrated a diminishing positive effect of the breadth of the star's expertise on a firm's innovative productivity ($\beta = 3.21$; $\beta = -4.85$; $p < 0.01$). Specifically, as the breadth of a star's expertise increases, the firm's innovative productivity increases, although a slight attenuation of this effect occurs at high levels (1.5 standard deviation above average) of breadth of expertise.

As reflected in Model 2 and consistent with Hypothesis 3a, we found a significant positive relationship between stars' collaborative strength and a firm's innovative productivity ($\beta = 0.83$; $p < 0.01$). To assess the joint effect of stars' collaborative strength and the breadth of their expertise on innovative productivity and to test Hypothesis 4a, we interacted these two predictors. As Model 2 shows, the linear effect of the interaction between stars' collaborative strength and breadth of expertise on firms' innovative productivity is positive and significant ($\beta = 0.68$; $p < 0.01$), and the square term is negative and significant ($\beta = -1.53$; $p < 0.01$). As predicted in Hypothesis 4a, our results suggest that stars with high collaborative strength increase their firm's productivity across all levels of expertise breadth relative to stars with low collaborative strength.

DOI: 10.1002/smj

Innovative leadership

Models 3 and 4 in Table 3 present the effects of the breadth of a star's expertise and collaboration on innovative leadership among non-star scientists in a firm. We tested Hypothesis 2b in Model 4. The results suggest that the breadth of a star's expertise has a positive effect on innovative leadership for both the linear and quadratic term, respectively ($\beta = 1.06$; $\beta = 0.27$; $p < 0.01$). Thus, we did not find support for a U-shaped relationship between star expertise breadth and innovative leadership. Instead, innovative leadership increases with breadth in a star's expertise, but at a decreasing rate.

The relationship between a star's collaborative strength and innovative leadership is positive and significant ($\beta = 0.57$; $p < 0.01$). To examine the joint effect of star scientist's collaborative strength and the breadth of their expertise on innovative leadership and to test Hypothesis 4b, we again interacted these predictors. As Model 4 shows, the linear effect of the interaction between collaborative strength and the breadth of a star's expertise on innovative leadership is positive and significant ($\beta = 0.27$; $p < 0.01$), and the square term is negative and significant ($\beta = -1.89$; $p < 0.01$). As predicted in Hypothesis 4b, the results suggest that firms experience the highest levels of innovative leadership when a star's expertise is broad and when the star has high collaborative strength, and the lowest levels of innovative leadership when a star's expertise is narrow and the star has weak collaborative strength.

Additional analysis

Our theory focuses on stars' effects on firms' innovative outcomes and when these effects vary. We examined whether the number of stars present in a firm affects these relationships in a supplemental analysis. As shown in Table 4, while the strength of the predicted relationships varies with the presence of multiple stars, the results are consistent with our original findings.

To test whether our focal theory of "global" star inventors (i.e., stars whose performance levels position them at the top of industry-wide standards) generalizes to "local" stars (i.e., individuals whose performance levels position them at the top of firm, but not industry-level standards), we developed a continuous measure of performance asymmetries among firms' scientists (Tzabbar, 2009). In an unreported analysis, we found that local stars have similar, yet significantly weaker, effects as global stars on firms' innovation outcomes.

We further tested whether our paper's findings vary based on whether innovation directly involves a star and/or occurs within versus outside a star's areas of expertise. As shown in Table 5, we find that a star's effect on innovative productivity is significantly stronger when the star serves as a co-inventor on patents and when innovation occurs within the star's area of expertise.

Table 5 also suggests that the presence of a star has a significant positive effect on innovative leadership within the star's area of expertise ($\beta = 0.09$; $p < 0.05$) and a significant negative effect on innovative leadership outside the star's area of expertise ($\beta = -1.53$; $p < 0.01$). These results suggest that a star's greater dependence on support from colleagues working within the star's area of expertise may result in increased balance in the star's relationships, contributing to increased opportunities for such colleagues' innovative leadership. In contrast, colleagues pursuing research outside a star's areas of expertise may have less balanced relationships with the star and thus enjoy fewer innovative leadership opportunities.

DISCUSSION

Our results highlight the duality of the effects that star employees have on their firms' performance. While stars benefit their organizations' productivity, their presence constrains the opportunities of other scientists in a firm to develop and use their innovative leadership capabilities. Our arguments and findings further demonstrate that the differential effects that stars have on their firms' research environments—based on their collaborative strength with colleagues and the breadth of stars' expertise—are important determinants of the effects stars have on their firms' innovative outcomes. As expected, relative to stars who collaborate rarely or not at all, the presence of stars with high collaborative strength improves both the productivity and innovative leadership opportunities of other scientists in a firm. Furthermore, our results indicate that a firm's innovative productivity and innovative leadership increase with greater breadth in a star's expertise (although the positive effect of expertise breadth on productivity diminishes at very high levels of breadth in expertise). Moreover, we show that both innovative productivity and

Table 4. Comparing results using current operationalization of star firm with results that account for number of star inventors

	Current operationalization of star firm		Number of stars	
	Productivity excluding star patents	Innovative leadership	Productivity excluding star patents	Innovative leadership
Star firm	0.22***	−1.41***		
	(0.03)	(0.12)		
Number of stars			0.14***	−1.63***
			(0.01)	(0.17)
Public firm	0.08**	0.01	0.09**	0.01
	(0.02)	(0.02)	(0.02)	(0.02)
Firm size (log)	0.13***	0.02 *	0.07***	0.06*
	(0.02)	(0.00)	(0.02)	(0.00)
Firm age (log)	0.14***	0.01	0.18***	0.01
	(0.03)	(0.00)	(0.03)	(0.00)
Venture capital (log)	0.09***	0.01***	0.06***	0.00***
	(0.01)	(0.00)	(0.01)	(0.00)
Scientist recruitment event	0.08*	−0.03***	0.12*	−0.01
	(0.02)	(0.00)	(0.02)	(0.01)
Geographic dispersion	−0.41***	0.08***	−0.36***	0.05***
	(0.09)	(0.01)	(0.09)	(0.01)
Prior R&D alliance	0.02*	−0.02**	0.01*	−0.07**
	(0.01)	(0.00)	(0.01)	(0.00)
CEO succession	0.04	0.02*	0.04	0.01
	(0.15)	(0.00)	(0.15)	(0.01)
Technological breadth	0.98***	0.48***	0.76***	0.53***
	(0.11)	(0.08)	(0.13)	(0.07)
Mills ratio: likelihood of recruiting star inventor	0.14***	−0.05***	0.14***	−0.05***
	(0.01)	(0.01)	(0.01)	(0.01)
Constant	1.57	−0.20	1.57	−0.20
	(0.15)	(0.02)	(0.15)	(0.02)
R^2	0.18	0.29	0.18	0.30
Wald χ^2	2309.91	1601.41	2323.06	1596.32

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

innovative leadership are highest in firms employing a star who has broad expertise and high collaborative strength. The results thus reinforce an important theme in the strategic human capital literature—namely, that the value of human capital is not absolute, but rather depends on how it is leveraged in a firm (Hitt *et al.*, 2001).

Implications and contributions

Our arguments and findings advance our understanding of the effects of star employees on the performance of their colleagues and firms in several ways. First, the prevailing wisdom suggests that star employees create disproportionate value for organizations by generating substantial increases in a firm's productivity (Rothaermel and Hess, 2007). Assuming such a static and monolithic view of the influence of stars in organizations underestimates the complex nature of stars' relationships with their colleagues and work environments. Moreover, the mechanisms by which such spillovers occur have yet to be theoretically grounded. By introducing a resource dependence perspective to this context, we capture the dual influences that stars exert on firms' innovative performance and account for the mutual dependence inherent in stars' exchanges within a firm. Further, the empirical findings that emerge from this perspective reinforce prior work, which suggests that stars are not all equal in their effects on colleagues' performance (Oettl, 2012) and that key individuals who are more central in a firm's workflow exert more significant influences on an organization's performance (Paruchuri, 2010).

The implications of our study extend beyond extant research on stars. In particular, by examining

DOI: 10.1002/smj

Table 5. Prediction of innovative productivity and leadership within and outside the star inventor's area of expertise

Variable	Productivity including star patents: Within star's area of expertise	Productivity including star patents: Outside star's area of expertise	Productivity excluding star patents: Within star's area of expertise	Productivity excluding star patents: Outside of star's area of expertise	Innovative leadership: Within star's area of expertise	Innovative leadership: Outside of star's area of expertise
Star firm	0.82***	0.31***	0.29***	0.06*	0.09*	−1.53***
	(0.05)	(0.09)	(0.03)	(0.03)	(0.04)	(0.09)
Public firm	0.11**	0.08**	0.08**	0.11**	0.01	0.01
	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
Firm size (log)	0.11***	0.20***	0.12***	0.15***	0.05*	0.01*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.00)	(0.00)
Firm age (log)	0.15***	0.18***	0.14***	0.09***	0.01	0.01
	(0.03)	(0.03)	(0.03)	(0.03)	(0.00)	(0.00)
Venture capital (log)	0.18***	0.09***	0.11***	0.06***	0.03***	−0.02*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
Scientist recruitment event	0.07**	0.19**	0.07*	0.13*	−0.03***	0.02*
	(0.01)	(0.01)	(0.02)	(0.02)	(0.00)	(0.01)
Geographic dispersion	−0.38***	−0.42***	−0.41***	−0.27	0.06***	0.09***
	(0.08)	(0.06)	(0.09)	(0.15)	(0.01)	(0.01)
Prior R&D alliance	0.03*	0.00	0.02*	0.02*	−0.02**	−0.02**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)
CEO succession	0.04	0.04	0.04	0.04	0.01*	0.05*
	(0.15)	(0.15)	(0.15)	(0.15)	(0.00)	(0.00)
Technological breadth	1.01***	1.16***	0.95***	1.01***	0.44***	0.53***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.09)	(0.08)
Mills ratio: likelihood of recruiting star inventor	0.13***	0.13***	0.14***	0.14***	−0.07***	−0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Constant	0.89	0.89	1.57	1.63	−0.21	−0.19
	(0.15)	(0.15)	(0.15)	(0.15)	(0.02)	(0.02)
R^2	0.23	0.17	0.19	0.17	0.33	0.27
Wald χ^2	2337.18	2182.22	2320.81	2284.06	1678.79	1551.16

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

the conditions under which stars' effects on organizations vary and highlighting the joint relationship between power imbalance and mutual dependence of a firm's inventors, we extend the testing of resource dependence theory to the intrafirm context. Consistent with Casciaro and Piskorski (2005), our findings reveal that within firms, the mutual dependence between social actors affects the relative influence and benefits that each actor enjoys in the exchange relationship and the extent to which these outcomes are balanced between individuals.

We also contribute to research on the effects of power and learning in organizations. Specifically, extant research in this vein suggests that power asymmetries stifle learning in organizations and calls for an examination of the mechanisms that may mitigate such constraining effects (Bunderson and Reagans, 2011). Our theory highlights two factors (i.e., breadth of expertise and levels of collaborative strength) that increase the mutual dependence between high status individuals and their colleagues, thereby reducing the power-related barriers to effective learning and improving other scientists' opportunities to achieve increased productivity in the presence of a star.

Finally, by examining the conditions under which stars' effects on their firms' performance vary, we advance research on the resource-based view (RBV) of the firm. Consistent with the RBV, we propose that when a firm's research program is tightly bound to and dependent on a star's research agenda, interdependencies within the firm are likely to be imbalanced, and the star's favorable effects on colleagues' performance are likely to be limited to positive spillovers that naturally occur in the course of the star's own innovative pursuits. In contrast, when behavioral interdependencies are more balanced and a firm embraces innovative aspirations that include developing quality human capital (i.e., among non-star scientists) that can enable and sustain its competitive advantage in the longer term, a star's knowledge and broader organizational resources are more likely to be leveraged to support other scientists' innovative capabilities.

Limitations

Relying on patent data to define our key variables raises some traditional concerns, including the objections that not all patentable knowledge gets patented (Alcacer and Gittelman, 2006; Griliches, 1990). Nevertheless, biotechnology firms are likely to patent any patentable technologies due to the strong appropriability regime for patents in this industry. Our archival data cannot reveal a firm's motives for hiring a star or selecting stars with particular characteristics. However, our regression analyses account for potential endogenous variables and firms' heterogeneity, thereby reducing the potential for alternative interpretations of our results. The risk of endogeneity and selection bias is also minimal, because our theory explores how the effects of stars vary. We emphasize that stars vary in their propensities to affect a firm's innovative performance, based on both the type of performance outcome and the factors that affect the mutual dependence in stars' exchanges with colleagues. Future research would benefit from an examination of outcomes tied to star mobility between firms. The limited number of star mobility events in our data prevented such an assessment in this study.

CONCLUSION

Organizational scholars and managers should also recognize that whereas stars may improve the overall productivity of their colleagues and firms and thus maximize an organization's opportunities for short-term performance gains, the presence of a star can also hinder other scientists' opportunities to develop as innovative leaders, which may threaten the long-term value associated with a firm's collective human capital. Further, stars may offer knowledge and resources that are not currently available to a firm, but firms rarely build innovative capabilities through this path alone. To exploit the benefits associated with employing a star, firms must motivate stars to share their knowledge, as well as grant other scientists opportunities to develop new skills while also learning how to lead innovation. Furthermore, factors that influence the mutual dependence between stars and their colleagues (such as a star's collaborative strength and breadth of expertise) are critical in determining the effects stars are likely to have on the innovative productivity and innovative leadership in their firms. Our study provides a deeper understanding of how the social interdependencies between stars and their colleagues shape stars' effects on firm performance.

ACKNOWLEDGEMENTS

We gratefully acknowledge the helpful comments and suggestions of Mark Huselid and David Lepak, as well as seminar participants at Drexel University. We also thank the editor and two anonymous reviewers for their support and constructive guidance throughout the review process. A previous version of this paper received an Honorable Mention for the Best Conference Paper Award at the 2011 Strategic Management Society meeting in Miami, Florida. The authors contributed equally and appear in alphabetical order.

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