COORDINATING AND COMPETING IN ECOSYSTEMS: HOW ORGANIZATIONAL FORMS SHAPE NEW TECHNOLOGY INVESTMENTS

RAHUL KAPOOR* and JOON MAHN LEE
The Wharton School, University of Pennsylvania, Philadelphia, Pennsylvania, U.S.A.
Krannert School of Management, Purdue University, West Lafayette, Indiana, U.S.A.

We consider firms in the context of their business ecosystems and explore how differences in the ways in which firms are organized with respect to complementary activities affect their decision to invest in new technologies. We argue that, in addition to creating differences in incentives and bureaucratic costs, firm-complementor organizational form plays an important role in the firm's ability to coordinate accompanying changes in complementary activities so as to shape the benefits from investing early in the new technology. We test our predictions in the U.S. healthcare industry from 1995–2006. The study makes a strong case for viewing firms' competitive strategies in the context of their business ecosystems and for the existence of an important link between firms' coordination choices and their strategic investments. Copyright © 2012 John Wiley & Sons, Ltd.

INTRODUCTION

The organization of activities within and outside firm boundaries has long been of interest to management scholars. The literature has uncovered different types of organizational forms that firms use to coordinate interdependent activities ranging from arm's-length relationships to more collaborative or hierarchical arrangements (e.g., Dyer and Singh, 1998; Mahoney, 1992; Williamson, 1991a). While a large number of empirical studies have examined the drivers and performance implications of firms' organizational forms (David and Han, 2004), surprisingly little attention has been devoted to examining how the choice of the organizational form influences the strategic investment decisions that underlie firms' performance outcomes

(e.g., Porter, 1980; Chandler, 1990). Some notable exceptions include Armour and Teece (1980), who examined how vertical integration affects firms' investments in research and development (R&D), and Mullainathan and Scharfstein (2001), who examined how vertical integration affects firms' investments in production capacity.

An emergent perspective in strategy views a firm's ability to create and appropriate value as critically dependent on actors that produce complementary products or services in the business ecosystem (Brandenburger and Nalebuff, 1996; Porter, 1998; Iansiti and Levien, 2004; Teece, 2007). In spite of the widespread recognition that the strategic interdependence between firms and complementors is gaining in importance, empirical evidence regarding how firms interact with complementors and the implications of such choices is relatively scarce (McIntyre and Subramaniam, 2009).

In this study, we consider the different types of organizational forms that firms could choose

to manage interdependent activities with complementors (e.g., Dyer and Singh, 1998; Williamson, 1991a). These include arm's-length relationships, collaborative alliances that vary in the scope of activities jointly carried out by firms and their complementors, and hierarchical relationships such that complementors are integrated within firms. We examine the implications of these organizational choices on an important type of strategic investment decision: the firm's decision to invest in a new technology (Dixit and Pindyck, 1994; Hall and Khan, 2003; Lieberman and Montgomery, 1988; McGrath, 1997).

We argue that a firm's ability to create value from a new technology will depend, in part, on the accompanying changes by complementors in the ecosystem who may need to undertake new investments and adapt their activities in order for the new technology to be successfully commercialized (Adner and Kapoor, 2010; Casadesus-Masanell and Yoffie, 2007; Teece, 2007). We draw on the organizational economics and strategy literatures to theorize how different types of organizational forms will be characterized by differences in incentives and bureaucratic costs as well as differences in the firms' ability to achieve coordinated adaptation so as to shape their relative benefits from investing early in the new technology (e.g., Williamson, 1991a). We test our arguments using an unusually rich longitudinal dataset that includes information on how firms are organized with respect to complementors and their technology investment decisions over a 12-year period.

The context for the study is the U.S. health care industry. We examine hospitals' decisions to invest in new medical imaging technologies. These technologies are used to visualize internal structures and processes within the human body and constitute some of the most important technical advances that have taken place in the health care industry (Burns *et al.*, 2013; Mitchell, 1989). We focus on two distinct imaging technologies: positron emission tomography (PET) and magnetic resonance imaging (MRI), which emerged at different periods during the industry's history. An attractive feature of the industry for the purpose of this study is that it is characterized by many different types of organizational forms chosen by hospitals to interact with physicians, their key complementors (Eggleston, Norman, and Pepall, 2004; Gaynor, 2006). Some hospitals interact with physicians through arm's-length relationships, while others interact

through alliances and yet others through fully integrated organizations in which physicians are employed by hospitals (Burns and Thorpe, 1993; Casalino and Robinson, 2003; Ciliberto and Dranove, 2006; Cuellar and Gertler, 2006). This feature allows us to explore how different types of hospital-physician relationships affect the hospital's propensity to invest in a new medical imaging technology. Another attractive feature of this context is that for the vast majority of hospitals, the choice of the organizational form was made well in advance of their decision to invest in the new imaging technologies.[1] Hence, we are able to mitigate the concern regarding potential reverse causality between a hospital's technology investment decision and the choice of the organizational form.

We find that for both MRI and PET technologies, hospitals pursuing alliances with physicians are more likely to invest in new imaging technologies than hospitals that either have an arm's-length relationship with physicians or are integrated and employ their own physicians. Among hospitals pursuing alliances with physicians, we find that the likelihood of investment in new imaging technologies is increasing in the scope of the alliance. These findings are robust to a number of alternative econometric specifications as well as additional analysis to account for the possibility of hospitals' self-selection into the different organizational forms.

The results from the study, while limited to a single industry and based on a specific type of technology, make a strong case for viewing firms' technology investment decisions in the context of the business ecosystem and for considering the different types of organizational forms that firms may use to manage complementary activities in the ecosystem. By examining a broad menu of organizational choices, we are able to explicitly consider the trade-offs associated with the different forms of organization and how they may affect the way firms compete in a given industry.

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[1] The different types of hospital-physician organizational forms emerged during the late 1980s as a result of entry by managed care organizations, which increased competition among service providers and shifted bargaining power from providers to payers. The health care literature has identified a number of hospital-level and industry-level factors that affected the choice of the hospital-physician organizational form (Cuellar and Gertler, 2006; Gal-Or, 1999; Robinson, 1999). We control for these effects in our analysis.

THEORY AND HYPOTHESES

Firms are embedded in a business ecosystem of interdependent activities carried out by their customers, complementors, and suppliers. These interdependencies underlie firms' ability to appropriate returns from investments in new technologies (Casadesus-Masanell and Yoffie, 2007; Adner and Kapoor, 2010). Hence, differences in how firms are organized with respect to such activities will have an important effect on their decision to invest in the new technology. For example, Helper (1995) considers how firms' relationships with customers affect their decision to invest in new technologies. She found that component suppliers in the automotive industry were more likely to invest in computer numerically controlled machine tool technology when they interacted through long-term contracts with their customers than when they interacted through arm's-length contracts. Mitchell and Singh (1996) found that firms competing in the hospital software systems industry varied significantly in the extent to which they pursued arm's-length or alliance-based relationships with their complementors (i.e., other software and hardware firms). While the authors did not observe firms' investment decisions, they found that firms pursuing alliance relationships were more likely to survive in the industry than firms pursuing arm's-length relationships. They interpreted this finding as providing support for the argument that firms pursuing an alliance mode were able to achieve better coordination during the commercialization of new products than firms using arm's-length relationships and hence derive greater benefits from their investments in new products.

We draw on the organizational economics and strategy literatures (e.g., Dyer and Singh, 1998; Gibbons, 2005; Williamson, 1985; 1991b) to explore how a firm's choice of organizational form with respect to complementary activities may affect its propensity to undertake new technology investments. We first outline the key features of the different organizational forms that are relevant to our arguments. We then link these features to the firms' propensities to undertake investments in new technologies.

Organizational forms and trade-offs

The literature in organizational economics has suggested that different forms of organization along the market-hierarchy continuum involve some important trade-offs (Williamson, 1991a). For the purpose of this study, we broadly categorize these trade-offs along the dimensions of 'cost of organization' and 'adaptability of organization' (e.g., Gibbons, 2005). The cost refers to the potential sources of inefficiencies that may be present within a given organizational form and that may interfere with the firm's ability to create value. It includes the intensity of incentives that reflect the extent to which parties are compensated for their contributions toward firm performance, as well as the bureaucratic costs associated with governance and decision making (Williamson, 1975; 1985). The adaptability of a given organizational form refers to the extent to which the firm can generate a coordinated response to changing market and technological circumstances characterized by high levels of uncertainty (Barnard, 1938; Williamson, 1991a; 1991b).[2] It entails the ability and willingness of interdependent parties to adapt their activities and undertake non-contractible investments during periods of change.

On the one hand, while the hierarchy form of organization enjoys advantage in adaptability as a result of superior communication channels, coordination routines, and allocation of decision rights, it suffers from higher organizational costs (Kogut and Zander, 1996; Williamson, 1991a). Drawing from organizational theory and economics, Williamson (1985: Chap. 6; 1975: Chap. 7) identifies the main drivers of higher organizational costs in hierarchies. These include impairment of incentives because of the difficulty of mimicking high-powered incentives of the markets characterized by a strong correspondence between the efforts expended and the payoffs appropriated by a given party within hierarchies. The absence of the disciplinary forces of markets also results in hierarchies having additional bureaucratic costs that stem from procurement practices that favor internal units despite a more profitable external alternative, persistence tendencies that favor continuation of unproductive or obsolete projects, and more general politicking underlying firms' operating and investment decisions.[3] Consistent with

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[2] We note that our treatment of the 'cost of organization' is not transaction-specific and hence it excludes transaction costs that we explicitly consider within the category of 'adaptability of organization.'

[3] Our discussion of bureaucratic costs is based on the 'theory of the firm' literature within organizational economics (cf.

these arguments, Milgrom and Roberts (1988; 1990) develop a formal theory of how authority in a hierarchy results in politicking, where parties lobby to influence decision makers for their own personal benefit. Such influence activities are costly, as they lower the quality of decision making and divert the attention and effort of parties from more productive activities. On the other hand, while the market form of organization enjoys lower bureaucratic costs and higher incentive intensity, the absence of authority and the existence of price-based coordination mechanism limit its adaptability (Simon, 1951; Williamson, 1975; 1991a).

The alliance form exhibits characteristics of a hybrid between markets and hierarchies (Borys and Jemison, 1989; Ménard, 2004). It provides greater incentives than hierarchies as partners retain autonomy over their tasks and the associated payoffs without a significant addition in bureaucratic costs (Oxley, 1997; Sampson, 2004; Teece, 1996; Williamson, 1991a). It also enables greater adaptability than markets, as cooperating partners develop communication channels and codes to facilitate knowledge sharing and coordination of interdependent investments and tasks (Doz, 1996; Dyer and Nobeoka, 2000; Dyer and Singh, 1998; Gulati, Lawrence, and Puranam, 2005; Zollo, Reuer, and Singh, 2002). While the alliance form may seem attractive for the above reasons, firms may be exposed to appropriability risk as partners seek to maximize their own benefits (Gulati and Singh, 1998). Also, there are limits to the adaptability of the alliance form, and hierarchy may still be superior for highly complex and uncertain activities (Nickerson and Zenger, 2004; Teece, 1996).

We now consider how these differences among organizational forms may shape firms' likelihood of investment in a new technology.

Organizational forms and firms' technology investment decisions

A firm's decision to make strategic investment in a new technology entails a large financial

commitment under uncertainty and presents the firm with important trade-offs (e.g., Dixit and Pindyck, 1994; Lieberman and Montgomery, 1988; McGrath, 1997; Mitchell and Singh, 1992; Reinganum, 1989). On the one hand, investing early in the new technology may allow a firm to improve its competitive position. On the other hand, given the technological and market uncertainty, investing early in a new technology may expose the firm to significant financial risk regarding whether it can profit from the new technology. We argue that differences in the relative cost and adaptability of market-, alliance-, and hierarchy-based organizational forms with respect to complementary activities may explain differences in the firms' propensities to invest in new technologies.[4]

Successful commercialization of a new technology often requires accompanying changes in complementary activities within the ecosystem (Adner and Kapoor, 2010; Hughes, 1983; Rosenberg, 1982). Hence, the commercialization phase of a new technology would entail coordinated adaptation by focal firms and complementors, who may need to incur new investments and adapt their activities during a period of technological and market uncertainty (Casadesus-Masanell and Yoffie, 2007; Mitchell and Singh, 1996; Teece, 2007). Coordinating such mutual adjustments between firms and complementors is an important driver of the firm's ability to benefit from investing early in the new technology. Besides adaptability, the cost of a given organizational form is likely to play an important role in the firm's decision to invest early in a new technology. Lower incentive intensity coupled with greater bureaucratic distortions would reduce the likelihood that a firm would pursue early (and risky) investment in the new technology (e.g., Teece, 1996).

As compared to market, the alliance form characterized by cooperation between partners has

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Williamson, 1975; 1985; Gibbons, 2005). These costs have been incorporated into the theoretical models in order to provide a more balanced comparative assessment of market and hierarchy forms of organization. However, we note that the empirical evidence regarding the different types of bureaucratic costs and their interaction with different types of organizational forms is relatively scarce and mostly anecdotal (Williamson, 1985; 1996).

[4] We note that there are some important boundary conditions with respect to the types of new technology investments that we consider within our theoretical framework. First, given our focus on complementary activities, our predictions do not apply in the case of firms choosing to invest in technologies that improve internal efficiency (e.g., information technology investments) but have little impact on complementary activities in the ecosystem. Second, while it is possible that some firms independent of their organizational forms may be locked out from investing in a specific technology standard (Schilling, 1998), this possibility is not explicitly considered within our theoretical framework. Hence, our predictions should be treated as *ceteris paribus*.

a relative advantage in adaptability (Williamson, 1991a), and hence in achieving coordinated adaptation during the commercialization of the new technology (Mitchell and Singh, 1996). While the alliance form may not enjoy the low organizational costs of markets, we argue that the organizational costs in a firm-complementor alliance are low enough so as not to completely nullify its relative advantage in adaptability. First, the theoretical development in the literature regarding incentive attenuation in alliances has focused on buyer-supplier relationships (e.g., Williamson, 1991a; Makadok and Coff, 2009). A buyer-supplier alliance where long-term contracts alter the market-based interaction between the supplier's effort and associated payoff can result in significant weakening of incentives and reduced effort by the supplier (Williamson, 1985). In contrast, a firm-complementor alliance does not alter the market-based interaction between complementors and their downstream buyers. This difference in the nature of interdependence underlying buyer-supplier alliance from the firm-complementor alliance ensures that complementors' payoffs continue to have a strong correspondence with their efforts and mitigates the incentive distortions that may exist in the traditional buyer-supplier alliance. Second, the persistence tendencies and more general politicking that represent important forms of organizational costs (Williamson, 1975; 1985) may only be applicable to investments that are incurred jointly by the alliance partners. In this study, our arguments pertain to the unilateral technology investments that are made by the focal firms rather than the bilateral technology investments that may be made by allying partners.

In summary, we suggest that as compared to firms pursuing arm's-length relationships with complementors, firms pursuing alliance relationships will be more effective in achieving the coordinated adaptation required to commercialize the new technology while limiting the corresponding increase in organizational costs. Hence, firms that have an alliance relationship with their complementors would be better positioned to create value from the new technology, and more likely to invest in the new technology than firms that have an arm's-length relationship.[5]

Hypothesis 1: Firms that have an alliance relationship with their complementors will be more likely to invest in a new technology than firms that have an arm's-length relationship.

While both hierarchy-based and alliance-based organizational forms enjoy superior adaptability over markets, the allocation of decision rights and greater efficiency in knowledge and information exchange make hierarchies more adaptable than alliances. This advantage will be particularly important when coordination tasks underlying the new technology commercialization are highly complex and uncertain (e.g., Nickerson and Zenger, 2004; Teece, 1996; Williamson, 1991a). Firms competing in a product market are more likely to invest in new technologies that preserve the value of their existing relationships and the associated complementarities in the ecosystem (Christensen and Rosenbloom, 1995; Mitchell, 1989; Tripsas, 1997). For such investments that typify many industrial contexts and in which the adaptation requirements within the ecosystem are likely to be of a "moderate" type, the adaptability benefits of hierarchies over alliances are likely to be small (Teece, 1996; Williamson, 1991a).

In contrast and as discussed above, the internalization of complementors and the creation of the authority relationship imposes significant organizational costs on firms. Teece (1996) refers to such costs as resulting in the 'anti-innovation bias' where firms may suffer not only from lower incentives to innovate but also from slower response to pursuing new technological opportunities.

Hence, as compared to firms pursuing hierarchy-based relationships with complementors, firms pursuing alliance relationships will be subject to significantly lower organizational costs while maintaining their ability to achieve coordinated adaptation during the commercialization of a new technology, and will be more likely to invest in the new technology.

Hypothesis 2: Firms that have an alliance relationship with their complementors will be more likely to invest in a new technology than firms that integrate into the complementary activities.

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[5] It is certainly plausible that an alliance between focal firms and complementors can also help to increase the focal firms' relative bargaining power over downstream buyers. This would increase the value that a firm can capture from the new technology and may be another reason for firms that have an alliance relationship with complementors to be more likely to invest in a new technology than firms that have an arm's-length relationship.

Alliance scope as a shift parameter

Research on alliances has suggested that the choice of alliance scope is among the most important choices considered by partnering firms (Doz and Hamel, 1998; Khanna, Gulati, and Nohria, 1998; Oxley and Sampson, 2004). Alliance scope refers to the extent of activities that partners jointly carry out through the alliance as compared to their total set of activities.

The broader the scope of activities carried out within the alliance, the greater the extent of common benefits that alliance partners derive from their relationships (Khanna *et al.*, 1998). Greater common benefits help to align the incentives between partnering firms and facilitate cooperation (Agarwal, Croson, and Mahoney, 2010; Dyer and Singh, 1998; Khanna *et al.*, 1998). Broader alliance scope would also make it easier for firms to identify and coordinate changes in the interdependent activities that will interact with the new technology. Hence, by both increasing organizational adaptability and by aligning incentives, greater alliance scope will increase the value that firms would derive from investing early in the new technology.

The combination of Hypotheses 1 and 2 suggests that we are proposing an inverted U-shaped relationship between the firm's organizational form along the market-hierarchy continuum and its propensity to invest in a new technology. We now suggest that the scope of the firm-complementor alliance, by affecting the extent of cooperation and coordination, can act as a shift parameter for the propensity of firms using the alliance mode to invest in a new technology. Hence, the broader the scope of the alliance between firms and their complementors, the greater the likelihood that firms would invest in a new technology.

Hypothesis 3: The broader the scope of the alliance between firms and their complementors, the greater the likelihood that firms will invest in a new technology.

Figure 1 illustrates the overall theoretical framework linking different types of organizational forms that firms could choose to interact with complementors and the likelihood of their investment in a new technology.

Figure 1. An integrative framework linking firm's organizational form with respect to complementors and its likelihood of investment in a new technology

METHODOLOGY

The context for our study is the U.S. health care industry from 1995 to 2006. We focus on the organizational forms pursued by hospitals and physicians and how they affect hospitals' propensity to invest in a new technology. While hospitals provide facilities and staff to diagnose and treat patients, physicians are the primary source of medical expertise for that diagnosis and treatment. The service provided by the physicians is a complement to the service provided by the hospitals, and hence physicians are key complementors to the hospitals (Brandenburger and Nalebuff, 1996: 12). The complementary relationship between hospitals and physicians has been acknowledged by Gaynor (2006) in his recent review of research on hospital-physician relationships in the health care literature. He notes that hospitals and physicians depend on each other for creating value and that their respective complementary services are sold downstream to the buyers. Eggleston *et al.* (2004) also discuss this complementary relationship between hospitals and physicians.

The health care industry provides an ideal context in which to explore the implications of the different types of organizational forms that firms could choose to manage their interdependence with complementors. The context is characterized by a wide variety of hospital-physician organizational forms that include arm's-length relationships, alliances with varying degrees of scope, and fully integrated organizations in which physicians are employed by hospitals (Burns and Thorpe, 1993; Casalino and Robinson, 2003; Ciliberto and Dranove, 2006; Cuellar and Gertler, 2006; Douglas and Ryman, 2003; Young, Charns, and Shortell, 2001).

The different types of hospital-physician organizational forms emerged during the late 1980s as a result of a shift in the industry in ways in which the health care services are delivered and reimbursed. Traditionally, the industry practiced the fee-for-service system in which patients were billed for each service provided and the claims were reimbursed from insurers. The insurers themselves did not play any part in the management of the delivery of services such that patients could get a service from any provider and receive a predetermined reimbursement for that service from the insurer. Because of the fragmented nature of the payment and delivery functions, health care costs rose rapidly (Weisbrod, 1991).

The growth in managed care organizations (MCOs) in the early 1980s was a response to this significant escalation of health care costs. MCOs integrated both the delivery of health care services and the payment functions, and focused on lowering health care costs while maintaining quality. A key feature of the MCO business model was to negotiate low rates with select providers (both hospitals and physicians) and to offer a variety of health plans to meet the needs of different market segments. By stimulating competition among health care providers in order for them to be considered in the network of service providers and by enforcing strict cost controls, especially for new and more expensive services, MCOs slowed the rate of increase in health care costs (Teisberg, Porter, and Brown, 1994). The growth of MCOs triggered greater competition among service providers and a relative shift in the bargaining power from providers to payers (Alexander, Morrisey, and Shortell, 1986). As a result, the industry witnessed the emergence of a variety of hospital-physician relationships intended to neutralize the higher bargaining power of MCOs, to gain efficiency by sharing costs for both hospital and physician services, to increase demand, and to improve the quality of care (Burns and Thorpe, 1993; Casalino and Robinson, 2003; Ciliberto and Dranove, 2006; Madison, 2004).

Data

The primary source of data for the study is the American Hospital Association (AHA), which since 1946 has conducted yearly surveys of all registered hospitals in the United States, with a greater than 80% response rate (AHA, 2009). Since 1995, AHA has been collecting information on the different types of organizational choices used by hospitals to interact with physicians. In this study, we use the AHA annual survey data from 1995 to 2006, supplemented with information on MCOs from the U.S. Department of Health and Human Services and with county-level demographic data from the Census Bureau.

The AHA database included information on 7,525 hospitals from 1995 to 2006. We excluded approximately eight percent of hospitals that reported using more than one type of organizational form with physicians. Following previous studies of technology adoption in the health care industry (e.g., Baker, 2001; David, Helmchen, and Henderson, 2009), we also excluded psychiatric, children's, and other specialty hospitals that have distinct business models or do not typically need to invest in the medical imaging technologies that we examine in this study. The final sample consisted of 5,367 hospitals.[6]

Measures

Dependent variable

We examine the hospital's decision to invest in new medical imaging technologies, which have been key drivers of technical advances in the health care industry (Burns *et al.*, 2013). We focus on two distinct imaging technologies that emerged at different periods in the industry. MRI is a diagnostic technology that captures high-resolution images of body tissues to detect anomalies such as tumors. While the origins of MRI date back to the early 1970s, its clinical use began around 1982. PET is among the most recent diagnostic technologies, commercialized in the early 1990s. PET provides a cross-sectional image based on metabolic activity of cells, which enables functional-level analysis of body tissues. Each of these imaging technologies constitutes a significant investment for a hospital (Baker, 2001; Teplensky *et al.*, 1995). A typical investment in these technologies includes capital expenditure in excess of $2 million to purchase the equipment and additional maintenance and personnel costs. As with most strategic investments, hospitals face the dilemma of whether and when to invest in these imaging technologies. An earlier

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[6] We performed additional analysis that included data from all 7,525 hospitals, and our results were consistent with those reported in the paper.

investment may allow a hospital to position itself as a technology leader (Luft *et al.*, 1986) and gain market share over its rivals (Ho, 2009). However, earlier investments are also made under considerable risk regarding the technical capability and implementation of the new technology, the extent of market demand, and the level of reimbursements that the hospital will receive from MCOs (Teplensky *et al.*, 1995).

Figure 2 shows the trend in the percentage of hospitals that have invested in MRI and PET technologies from 1995 to 2006. Our dependent variable measures whether a hospital has invested in the new imaging technology in a given year. A hospital is assumed to have invested in the new technology during the first year that it reports the technology's availability in the AHA annual survey.

In some instances, there was inconsistency in the reported data. A hospital might report the technology as available one year but not the next. In other cases, a hospital reported the availability of the technology in one year but the data were missing the following year and resumed in later years. We tested for the robustness of our findings by following the procedure used by Baker (2001). Specifically, in the case of inconsistent data, we used as the year of new technology investment the earliest of the first two consecutive years in which the hospital reported the availability of the focal technology. For example, when a hospital reported the availability of the technology in 1995, 1997, and 1998 but not in 1996, we consider the year of investment to be 1997. In the case of missing data, we chose the year of new technology investment as the earliest of the first three successive years in which the hospital reported the availability of the focal technology. For example, when a hospital

reported the availability in 1995, 1997, and 1998 but the data were missing in 1996, we consider the investment year to be 1995. The results using this procedure to code the technology investment event were fully consistent with our reported results.

Independent variables

The AHA survey identified hospital-physician organizational form based on six different categories used in the industry. On the one end of the continuum, an arm's-length relationship between hospitals and physicians entails that while physicians have admitting privileges in hospitals, they remain independent with respect to contracting with MCOs, administrative tasks, and information systems. On the other end of the continuum, an Integrated Salary Model (ISM) entails that hospitals use an integrated organizational form and employ their own physicians.

Between the arm's-length and integrated modes, four different types of alliance forms are extensively used by hospitals and physicians (AHA, 2009; Cuellar and Gertler, 2006; Robinson, 1999). A key distinguishing factor among these hybrid choices is the scope of the activities that are carried out through the alliance relationship. First, the Independent Practice Association (IPA) alliance entails that hospitals and physicians pursue joint contracting with MCOs while retaining autonomy over administrative tasks and information systems. An IPA alliance is relatively easy to organize and incurs minimal setup costs. Second, the Open Physician Hospital Organization (OPHO) alliance is responsible for coordinating administrative tasks between hospitals and physicians as well as negotiating and managing contracts with MCOs. Third, in the Closed Physician Hospital Organization (CPHO) alliance, physicians are exclusively contracted to the hospitals, and the scope of the alliance also extends to coordinating care for the patients. Finally, the Management Service Organization (MSO) alliance emulates most of the features of the CPHO alliance except that the alliance is also responsible for supporting the services of the physicians through staff and equipment. The MSO's services include office support, purchasing and operation of information systems, patient billings and collections, and contract marketing and negotiations (Brown, 1996).

We measured hospital-physician organizational form with dummy variables that were coded based

Figure 2. Percentage of hospitals that have invested in PET and MRI imaging technologies

on the discrete categories used in the AHA survey. Our base category of organizational form is an arm's-length relationship between hospitals and physicians. The variable *complementor alliance* took a value of 1 if the hospital used any of the four different types of alliance with physicians—IPA, OPHO, CPHO, or MSO—and 0 otherwise. The variable *complementor integration* took a value of 1 if the hospital reported using an ISM.

In order to test its effect, we created separate categories of low, medium, and high alliance scope. Our categorization is based on the rank ordering of the extent of activities that hospitals and physicians carry out through the alliance as compared to their total set of activities (Khanna *et al.*, 1998). An IPA alliance was categorized as *low alliance scope*. An OPHO alliance was categorized as *medium alliance scope*. Finally, a hospital that used either a CPHO or MSO alliance was categorized as having *high alliance scope*. While CPHO and MSO alliance forms are very similar in their scope, as a test of robustness, we estimated a model that included their separate effects. The coefficients and the significance levels were almost identical to those of the aggregated category.

Control variables

We controlled for a number of hospital- and market-level covariates that may affect a hospital's propensity to invest in a new technology. Consistent with the health care literature, *hospital size* is measured as the total number of beds. We used dummy variables to characterize the different business models used by hospitals and that may be correlated with their competitive positioning, incentives to invest in new technologies, and quality of care (e.g., Kupersmith, 2005; Sloan, 2000). These dummy variables include *medical school member, teaching school member, not-for-profit,* or *government owned*. The hospital's *capacity utilization* is measured as the ratio of annual inpatient days to the annual capacity of the hospital, obtained by multiplying the total number of hospital beds with 365 (Banker, Conrad, and Strauss, 1986). The hospital's *outpatient ratio* is measured as the ratio of annual outpatient visits to the annual inpatient admissions (Ciliberto, 2006). A hospital typically works with a number of MCOs that distribute its services. Many of these interactions are governed through arm's-length relationships. However, several hospitals reported having

an equity interest in at least one of the MCOs.[7] For example, Sanpete Valley Hospital (Mount Pleasant, Utah) has an equity interest in Intermountain Healthcare MCO, which is a distributor of its services in addition to other independent MCOs such as Altius Healthplans and Healthy U. We expect that such a relationship would increase a hospital's bargaining power over MCOs and make it more likely to invest in the new imaging technology. We used a dummy variable, *MCO equity interest,* to identify such hospitals.

The market-level controls include the *Number of General Hospitals* in the county where the hospital is located and *Market Concentration,* measured as the Herfindahl-Hirschman index (HHI) of hospital market shares in the county. We controlled for the county's demographic characteristics through *Unemployment Rate* and *Per Capita Income*.

Many recent studies in the health care literature have reported that the emergence of MCOs in the 1980s imposed excessive economic constraints on hospitals through lower reimbursement rates and strict cost controls. As a result, these studies found that greater market penetration of MCOs over traditional insurance organizations have lowered the propensity of hospitals to invest in new technologies (e.g., Baker, 2001; Douglas and Ryman, 2003; Mas and Seinfeld, 2008). The literature has used different data sources to measure the penetration of MCOs in a given geographical market. For example, scholars have used information on health maintenance organizations (HMOs) or Medicare to measure MCO penetration (e.g. Baker, 1997; Dranove, Simon, and White, 1998). In this study, we used Medicare data from the Area Resource File provided by the U.S. Department of Health and Human Services to measure managed care penetration (e.g., Baker, 1997). We control for this effect through the variable *MCO penetration,* which takes a value of 1 if the percentage of Medicare enrollees in the county exceed 15 percent and 0 otherwise. We used a dichotomous rather than a continuous measure in order to account for the nonlinear relationship between MCO penetration and hospitals' technology investments as shown by Baker (2001). We tested for the robustness of our findings by using the alternative HMO penetration level information for the year 1998 obtained from the Area

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[7] The question in the AHA survey specifically asked about an equity interest in either Health Maintenance Organizations (HMOs) or Preferred Provider Organizations (PPOs), the two most common forms of MCOs.

Table 1. Description of variables

Variables	Description
Dependent variable	
Hospital's technology investment	Dummy=1 for the year the hospital invested in the technology
Independent variables	
Complementor alliance	Dummy=1 for the hospitals that have an alliance relationship with physicians
Low alliance scope	Dummy=1 for the hospitals that use IPA alliance form
Medium alliance scope	Dummy=1 for the hospitals that use OPHO alliance form.
High alliance scope	Dummy=1 for the hospitals that use CPHO and MSO alliance forms
Complementor integration	Dummy=1 for the hospitals that have an integrated salary model and employ physicians
Control variables	
Hospital effects	
Hospital size	Number of beds in the hospitals
MCO equity interest	Dummy=1 for the hospitals that have an equity relationship with an MCO
Medical school affiliation	Dummy=1 for the hospitals that are members of a medical school association
Teaching school member	Dummy=1 for the hospitals that are affiliated with a teaching school association
Not-for-profit	Dummy=1 for the hospitals that are owned by not-for-profit institutions
Government owned	Dummy=1 for the hospitals that are owned by the government
Outpatient ratio	The ratio of annual outpatient visits to annual inpatient admissions for a given hospital
Capacity utilization	The ratio of the hospital's annual inpatient days to the number of beds multiplied by 365
Competitive effects	
Market concentration	HHI index based on the hospitals' share of beds in a given county
Number of hospitals	Number of general hospitals in a given county
MCO effect	
MCO penetration	Dummy=1 if Medicare managed care penetration is greater than 15%
Demand effects	
Unemployment rate	Unemployment rate in % for those 16 years and older in a given county
Per capita income	Per capita income of the county divided by 10,000

Resource File. While the standard error for the MCO penetration estimate was larger, the magnitude and significance levels of our hypothesized covariates remain almost unchanged.

Finally, we include state fixed effects to control for unobserved differences in health care regulation (e.g., certificate of need) across the different states (Hillman and Schwartz, 1985). Table 1 provides a brief summary of the variables used in the analysis.

Analysis

Many hospitals in our sample did not invest in the medical imaging technologies during the period of observation. Hence, our data is right-censored. We used event history models to account for the right-censored observations and to incorporate time-varying covariates into our analysis. Consistent with prior studies examining hospitals' timing of investments into new technologies, we used the Cox semiparametric proportional hazards model

(e.g., Mas and Seinfeld, 2008; Teplensky *et al.*, 1995). The Cox model allows for a fully flexible, nonparametric baseline hazard, and hence does not require making additional assumptions about the shape of the baseline hazard over time (Cox, 1975). We used the Efron approximation method to handle the event ties. The Efron method is computationally more intensive than the Breslow method but performs a more accurate approximation (Cleves, Gould, and Gutierrez, 2008). As a robustness check, we also performed our estimations using a parametric model, with the baseline technology adoption hazard assumed to follow a Weibull distribution (e.g., Escarce, 1996; Karshenas and Stoneman, 1993) as well as a piecewise constant model with year-specific effects. The results from the Weibull and the piecewise constant models were fully consistent with those from the Cox model.

A number of hospitals in our sample had invested in the MRI technology prior to 1995, and hence these observations were left-censored. We

follow the standard approach in the literature of excluding these left-censored observations (Allison, 1982). To ensure that our results are not biased by this exclusion, we separately estimated a cross-sectional probit model for all hospitals in the year 1995. The results from the probit model, reported in the robustness checks section, are qualitatively similar to the results obtained from the Cox model.

RESULTS

Tables 2a and 2b show the summary statistics and correlations between our covariates for the two different medical imaging technologies. Table 3 reports the results from the Cox models. Models 1 and 4 are our baseline models for the hospitals' adoption of PET and MRI technologies, respectively. Models 2 and 3 allow us to test our predictions using data from hospitals' adoption of PET technology, and Models 5 and 6 allow us to test our predictions using data from hospitals' adoption of MRI technology.

The results from the baseline models are consistent with our expectations and prior research in the health care industry (e.g., Baker and Phibbs, 2002; Hillman and Schwartz, 1985; Robinson, 1996; Teplensky *et al.*, 1995). On the one hand, hospitals that are large, are not-for-profit, are members of a medical school association, and have greater capacity utilization are more likely to invest in the new medical imaging technologies. On the other hand, hospitals that have a greater outpatient ratio and are located in more concentrated markets are less likely to invest in the new technologies. The estimates for MCO penetration are negative and significant for both PET and MRI technologies. Hence, our results provide continued support of prior findings that the emergence of MCOs is negatively correlated with hospitals' investments in new technologies (Baker, 2001; Baker and Phibbs, 2002; Mas and Seinfeld, 2008). The coefficient for *MCO equity interest* is positive and significant. Hospitals that have an equity interest in at least one of the MCOs are more likely to invest in the new imaging technologies than hospitals that transact with MCOs primarily through arm's-length contracting. The coefficient for the number of hospitals is negative but insignificant

While we expected hospitals that are members of a teaching school association to be more likely to

invest in the new technologies, we found this effect to be positive and significant only for the PET technology. The significant and negative effect for MRI technology could be due to the fact that many of these hospitals that had invested in the MRI technology were left-censored and hence excluded from the sample. This was confirmed in our estimates from the probit model using the left-censored data. Finally, the coefficient for *not-for-profit* was negative and significant for MRI technology only.[8]

In Hypothesis 1, we predicted that firms that have an alliance relationship with their complementors will be more likely to invest in a new technology than firms that have an arm's-length relationship. This prediction was supported for both technologies (Models 2 and 5). Note that our baseline category is the arm's-length relationship between the hospitals and the physicians. The coefficients for complementor alliance are significant and positive for both PET and MRI technologies. In considering the magnitude of estimated coefficients, we see that hospitals that have an alliance relationship with physicians are 27 percent (37%) more likely to invest in the PET (MRI) technology than hospitals that have an arm's-length relationship with physicians.

In Hypothesis 2, we predicted that firms that have an alliance relationship with their complementors will be more likely to invest in a new technology than firms that integrate into the complementary activities. The coefficient for complementor integration is insignificant for both PET and MRI technologies. A comparison of the coefficients for complementor alliance with those for complementor integration using the Wald test (Table 4) reveals support for Hypothesis 2.

In Hypothesis 3, we predicted that a firm's propensity to invest in the new technology is increasing in the scope of the firm-complementor alliance. Consistent with our hypothesis, the coefficient for alliance scope in Table 4 is increasing in the scope of the alliance. With the exception of low alliance scope for the PET technology, all of the alliance scope coefficients are positive and significant. Hospitals with low alliance scope are 24 percent more likely to invest in the

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[8] We note that studies in the health care industry have generally found mixed results with respect to differences in technology investments between for-profit and not-for-profit hospitals (e.g., Mas and Seinfeld, 2008).

Table 2a. Descriptive statistics for PET technology dataset

	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 PET investment	0.035	0.184	1																	
2 Complementor alliance	0.248	0.432	0.03	1																
3 Low alliance scope	0.089	0.285	0.00	0.55	1															
4 Medium alliance scope	0.101	0.301	0.02	0.58	−0.10	1														
5 High alliance scope	0.058	0.234	0.03	0.43	−0.08	−0.08	1													
6 Complementor integration	0.178	0.382	0.01	−0.27	−0.15	−0.16	−0.12	1												
7 MCO equity interest	0.108	0.311	0.01	0.11	0.03	0.09	0.05	0.02	1											
8 Hospital size	138.158	146.569	0.19	0.07	−0.01	0.05	0.07	0.00	0.07	1										
9 Medical school affiliation	0.234	0.424	0.08	0.01	−0.02	0.00	0.04	0.03	0.05	0.41	1									
10 Teaching school member	0.040	0.195	0.11	−0.01	−0.02	−0.03	0.04	0.06	0.02	0.42	0.36	1								
11 Not-for-profit	0.553	0.497	0.04	0.05	−0.02	0.07	0.01	0.01	0.01	0.13	0.07	−0.02	1							
12 Government owned	0.320	0.467	−0.05	−0.08	−0.01	−0.08	−0.04	0.07	0.00	−0.14	−0.03	0.06	−0.76	1						
13 Market concentration	0.575	0.361	−0.09	−0.07	−0.04	−0.02	−0.05	0.04	0.00	−0.42	−0.27	−0.23	−0.09	0.22	1					
14 Number of hospitals	6.196	14.047	0.04	0.06	0.11	−0.01	0.00	−0.04	−0.01	0.23	0.12	0.10	0.01	−0.12	−0.49	1				
15 MCO penetration	0.295	0.456	0.03	0.02	0.06	−0.04	0.00	0.01	−0.01	0.14	0.05	0.08	0.03	−0.09	−0.32	0.33	1			
16 Outpatient ratio	26.656	44.323	−0.03	−0.06	−0.04	−0.04	−0.01	0.11	−0.01	−0.15	−0.04	0.00	−0.06	0.14	0.08	−0.08	−0.01	1		
17 Capacity utilization	0.545	0.518	0.03	0.00	0.00	0.01	0.00	0.01	0.01	0.15	0.07	0.08	0.06	−0.05	−0.11	0.07	0.05	−0.06	1	
18 Unemployment rate	541.334	247.566	−0.02	0.00	0.02	0.00	−0.03	−0.03	0.03	−0.07	−0.04	−0.04	−0.07	0.05	0.05	0.03	−0.02	0.01	−0.02	1
19 Per capita income	23990.180	7436.412	0.13	0.03	0.02	0.00	0.03	0.04	−0.04	0.27	0.13	0.17	0.14	−0.18	−0.44	0.24	0.26	−0.01	0.09	−0.26

Correlations greater than 0.01 or smaller than −0.01 are significant at $p < 0.05$, N = 37 382.

Table 2b. Descriptive statistics for MRI technology dataset

		Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	MRI investment	0.124	0.330	1																	
2	Complementor alliance	0.215	0.411	0.10	1																
3	Low alliance scope	0.093	0.290	0.03	0.61	1															
4	Medium alliance scope	0.078	0.269	0.06	0.56	−0.09	1														
5	High alliance scope	0.044	0.206	0.08	0.41	−0.07	−0.06	1													
6	Complementor integration	0.186	0.389	−0.04	−0.25	−0.15	−0.14	−0.10	1												
7	MCO equity interest	0.101	0.301	0.03	0.09	0.03	0.07	0.04	0.02	1											
8	Hospital size	101.937	121.583	0.24	0.07	0.00	0.06	0.05	0.00	0.06	1										
9	Medical school affiliation	0.204	0.403	0.08	0.02	0.00	0.01	0.03	−0.01	0.04	0.35	1									
10	Teaching school member	0.019	0.138	0.09	0.02	0.00	0.00	0.04	0.03	0.03	0.39	0.27	1								
11	Not-for-profit	0.505	0.500	0.07	0.05	−0.01	0.08	0.01	0.00	−0.01	0.14	0.05	0.02	1							
12	Government owned	0.390	0.488	−0.12	−0.07	0.01	−0.09	−0.03	0.07	0.02	−0.16	−0.04	0.00	−0.81	1						
13	Market concentration	0.628	0.353	−0.14	−0.08	−0.05	−0.04	−0.04	0.04	−0.01	−0.40	−0.22	−0.18	−0.11	0.22	1					
14	Number of hospitals	5.153	12.636	0.09	0.07	0.10	0.00	−0.01	−0.04	−0.01	0.25	0.12	0.10	0.02	−0.13	−0.48	1				
15	MCO penetration	0.262	0.440	0.07	0.03	0.06	−0.03	0.00	0.03	0.00	0.14	0.03	0.07	0.02	−0.08	−0.29	0.32	1			
16	Outpatient ratio	41.756	1330.440	−0.01	0.00	0.00	0.00	0.00	0.00	0.00	−0.01	0.01	0.00	−0.01	0.02	0.00	0.00	0.00	1		
17	Capacity utilization	0.515	0.294	0.05	0.00	−0.01	0.02	−0.01	0.04	0.01	0.29	0.11	0.10	0.11	−0.11	−0.20	0.14	0.08	0.00	1	
18	Unemployment rate	558.218	269.249	−0.04	−0.02	0.00	−0.01	−0.03	−0.05	0.04	−0.06	−0.01	−0.03	−0.07	0.05	0.04	0.02	−0.02	0.00	−0.02	1
19	Per capita income	2266.360	6722.576	0.14	0.04	0.01	0.03	0.03	0.05	−0.04	0.27	0.06	0.14	0.13	−0.19	−0.42	0.25	0.27	0.00	0.15	−0.28

Correlations greater than 0.01 or smaller than −0.01 are significant at $p < 0.05$, N = 19 241.

Table 3.   Cox proportional hazards estimates for hospital's investment into new imaging technologies

	PET technology			MRI technology		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Complementor alliance		0.238***			0.312***	
		(0.066)			(0.048)	
Low alliance scope			0.098			0.212***
			(0.105)			(0.069)
Medium alliance scope			0.239***			0.257***
			(0.091)			(0.069)
High alliance scope			0.386***			0.553***
			(0.102)			(0.077)
Complementor integration		0.044	0.045		−0.053	−0.051
		(0.079)	(0.079)		(0.064)	(0.064)
MCO equity interest	0.180**	0.148*	0.152*	0.289***	0.248***	0.256***
	(0.086)	(0.087)	(0.087)	(0.064)	(0.064)	(0.064)
Hospital size	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Medical school affiliation	0.283***	0.287***	0.278***	0.458***	0.481***	0.479***
	(0.075)	(0.075)	(0.075)	(0.060)	(0.060)	(0.060)
Teaching school member	0.316***	0.326***	0.322***	−0.240**	−0.263**	−0.273**
	(0.103)	(0.103)	(0.103)	(0.112)	(0.112)	(0.112)
Not-for-profit	0.136	0.131	0.127	−0.183***	−0.187***	−0.184***
	(0.090)	(0.090)	(0.091)	(0.064)	(0.064)	(0.064)
Government owned	−0.263**	−0.253**	−0.253**	−0.582***	−0.563***	−0.555***
	(0.108)	(0.108)	(0.108)	(0.073)	(0.073)	(0.073)
Market concentration	−0.676***	−0.689***	−0.676***	−0.442***	−0.441***	−0.438***
	(0.120)	(0.120)	(0.120)	(0.086)	(0.086)	(0.086)
Number of hospitals	−0.001	−0.001	−0.001	−0.000	−0.001	−0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
MCO penetration	−0.136*	−0.126*	−0.127*	−0.153***	−0.148***	−0.148***
	(0.071)	(0.071)	(0.071)	(0.054)	(0.054)	(0.054)
Outpatient ratio	−0.004***	−0.004***	−0.004***	−0.006***	−0.006***	−0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Capacity utilization	0.048**	0.048**	0.048**	−0.026	−0.018	−0.020
	(0.021)	(0.021)	(0.021)	(0.074)	(0.071)	(0.072)
Unemployment rate	−0.068***	−0.068***	−0.066***	−0.049***	−0.048***	−0.047***
	(0.017)	(0.017)	(0.017)	(0.011)	(0.011)	(0.011)
Per capita income	−0.083**	−0.088**	−0.082**	−0.263***	−0.271***	−0.271***
	0.048**	0.048**	0.048**	−0.026	−0.018	−0.020
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Investment events	1296	1296	1296	2365	2365	2365
Hospitals	5367	5367	5367	3947	3947	3947
Observations (hospital-years)	36,828	36,828	36,828	18,916	18,916	18,916
Log likelihood	−10,061	−10,054	−10,052	−17,535	−17,510	−17,503

Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$ Our baseline category of hospital-physician organizational form is the arm's-length relationship.

MRI technology than hospitals that have an arm's-length relationship with physicians. Hospitals with medium alliance scope are 27 percent (30%) more likely to invest in the PET (MRI) technology than hospitals that have an arm's-length relationship with physicians. Finally, hospitals with high alliance scope are 47 percent (73%) more likely to invest in the PET (MRI) technology than

hospitals that have an arm's-length relationship with physicians. A comparison of the coefficients for the low and high alliance scope using the Wald test supports Hypothesis 3 for both technologies. However, the difference between the coefficients for the medium and high alliance scope was significant only for MRI technology, and the difference between the coefficients for the low and medium

Table 4. Difference between coefficient estimates using Wald test

PET technology	Null hypothesis	Chi^2(2)	Prob > chi^2
H2	Complementor alliance = complementor integration	5.19	0.023
H3	Low Alliance scope = medium alliance scope	1.25	0.264
H3	Medium alliance scope = high alliance scope	1.43	0.232
H3	Low alliance scope = high alliance scope	4.61	0.032

MRI technology	Null hypothesis	Chi^2(2)	Prob > chi^2
H2	Complementor alliance = complementor integration	28.81	0.000
H3	Low alliance scope = medium alliance scope	0.26	0.611
H3	Medium alliance scope = high alliance scope	9.90	0.002
H3	Low alliance scope = high alliance scope	12.90	0.000

alliance scope was insignificant for both PET and MRI technologies, suggesting a moderate support for Hypothesis 3.

Robustness checks

An important issue to consider with our analysis is the possibility of hospitals self-selecting into the different organizational forms, which could potentially bias our estimates. In order to test the robustness of our results to this potential endogeneity bias, we used a matching estimator approach. Matching estimators have been widely used in economics and have recently been used by scholars in management to address selection bias in empirical specifications (e.g., Rawley and Simcoe, 2009; Sampson, 2005; Zhao, 2009). This nonparametric approach compares the statistical results obtained in a treatment group with those obtained in a comparable control group. The main purpose of the matching estimator is to try to reestablish the conditions of a natural experiment so that the comparison between the two groups allows for a causal inference. We use matching estimators to evaluate the effect of hospital-physician organizational form on hospitals' propensity to invest in new imaging technologies. Our control group is drawn from the hospitals that maintained the same organizational form throughout the period of study. Our treatment group is drawn from the hospitals that shifted their organizational form.

We briefly illustrate the specification that we use to estimate our results. Let i index the hospital in our sample, and let T be a dummy variable that takes the value of 1 if the hospital shifts its organizational form and 0 otherwise. Let $Y_i(T)$ represent the hospital's decision to invest in the new technology. So $Y_i(0)$ represents the hospital's decision to invest if it had maintained its organizational form, and $Y_i(1)$ represents the *same* hospital's decision to invest if it had shifted its organizational form. Clearly, if both results were simultaneously observed, the effect of the hospital-physician organizational choice for hospital i, $Y_i(1) - Y_i(0)$, would be directly observable. The population average of this effect could be obtained as $E[Y(1) - Y(0)]$, and its sample counterpart as $(1/N) \sum_{i=1}^{N} [Y_i(1) - Y_i(0)]$, where N is the number of hospitals. However, $Y_i(1)$ and $Y_i(0)$ are not simultaneously observable. For example, in our study, we cannot observe the same hospital shifting from alliance to integration and maintaining the alliance mode as well. In other words, the two events—shifting and maintaining the organizational form—are mutually exclusive.

The matching estimators provide an alternative approach. Let j (while $i \neq j$) index the hospitals in our sample, and assume that hospitals i and j closely match each other based on the observables. By observing $Y_i(0)$ and $Y_j(1)$, we can use $Y_j(1)$ as a counterfactual value of $Y_i(1)$. We use the bias-corrected nearest-neighbor matching estimator proposed by Abadie and Imbens (2006) to find the counterfactual value.[9] For each hospital i, the standard nearest-neighbor matching estimator searches for the most similar hospital with the opposite treatment. We match hospitals based on hospital attributes, MCO penetration, market concentration, and demand effects. Figures 3 and 4 plot the kernel densities of the propensity scores for treatment and control groups before and after

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[9] This was implemented in STATA 10.0 using the NNMATCH procedure provided by Abadie *et al.* (2004).

Figure 3. Propensity score of treatment (arm's-length) and control (alliance) groups before and after matching (PET technology)

Figure 4. Propensity score of treatment (integrated) and control (alliance) groups before and after matching (MRI technology)

matching. The effectiveness of our matching procedure is evident from greater similarity in kernel densities between the groups after matching than between the groups before matching.

Our main results are supported if we find that the difference in the likelihood of investment between the treatment and the control groups is significant in our predicted direction. For example, with respect to Hypothesis 1, our control group comprises hospitals that use an alliance mode, and the matched treatment group comprises hospitals that shift from an alliance to an arm's-length relationship with physicians. Hypothesis 1 is supported if we find that the hospitals in the treatment group are less likely to invest in the new imaging technology than similar hospitals in the control group. The results, reported in Table 5, are fully supportive of

Hypotheses 1 and 2. While we would have preferred to use this methodology to test the robustness of Hypothesis 3 as well, we are limited by our data. Only a small number of hospitals have changed the scope of the alliance during the period of study, and hence we are unable to create large enough control and treatment groups to generate precise estimates.

Another potential concern with our analysis is that in estimating the hospital's likelihood of investment in MRI technology, we excluded a large number of hospitals that had adopted the technology prior to our window of observation. It is possible that the exclusion of these left-censored observations may have created a selection bias in our sample. To ensure that our results for the MRI technology are not biased by the exclusion of these

Table 5.   Sample average treatment effect for hospital's investment in PET technology

Hypothesis	Predicted sign	Coefficient[a]	Hospitals in treatment group
H1 (Complementor alliance vs. arm's-length)	-ve	−0.068** (0.039)	144 (Alliance to arm's-length)
H2 (Complementor alliance vs. integration)	-ve	−0.062** (0.036)	306 (Alliance to integration)

[a] Sample average treatment effect for the treatment group
* Standard errors in parentheses, ** $p<0.05$

hospitals, we performed a cross-sectional analysis using a probit model for the year 1995, the first year of observation in the study. The estimated results from the probit model, reported in Table 6, are nearly identical to the results from the Cox models and provide additional support for our predictions.

Finally, we checked whether our findings are driven by hospitals changing their organizational form contemporaneously with their investments in the new technology. We performed an additional analysis by excluding data from 122 hospitals that reported their adoption of the new technology and a switch in their organizational form in the same year. We did this only for PET technology, as the data for MRI technology is left-censored with a significant proportion of hospitals adopting the MRI technology prior to the first year of observation. The results were robust to this sensitivity analysis.

DISCUSSION

In this study, we consider the interdependencies that exist between focal firms and complementary activities in the business ecosystem, and we explore how differences in the firms' mode of organization with respect to such activities affect their decision to invest in new technologies. We examine a broad menu of organizational forms that firms may pursue in a given industry. These include arm's-length relationships, hierarchies, and alliances that vary in the scope of activities jointly carried out by the partners (Williamson, 1991a; Doz and Hamel, 1998). We draw on the organizational economics and strategy literatures to argue that differences in organizational forms represent differences in the organizational costs characterized by the intensity of incentives and bureaucratic costs as well as differences in the firms' ability to

Table 6.   Probit estimates for a hospital's investment in MRI technology in 1995

	Model 7	Model 8
Complementor alliance	0.351*** (0.058)	
Low alliance scope		0.132 (0.089)
Medium alliance scope		0.436*** (0.082)
High alliance scope		0.518*** (0.100)
Complementor integration	−0.160* (0.085)	−0.156* (0.085)
MCO equity interest	0.171** (0.067)	0.160** (0.067)
Hospital size	0.002*** (0.000)	0.002*** (0.000)
Medical school affiliation	0.174** (0.085)	0.167** (0.085)
Teaching school member	0.027 (0.132)	0.033 (0.133)
Not-for-profit	−0.117 (0.088)	−0.121 (0.088)
Government owned	−0.502*** (0.094)	−0.500*** (0.094)
Market concentration	−0.282*** (0.101)	−0.277*** (0.102)
Number of hospitals	−0.008*** (0.002)	−0.007*** (0.002)
MCO penetration	0.002 (0.096)	0.008 (0.097)
Outpatient ratio	−0.007*** (0.002)	−0.007*** (0.002)
Capacity utilization	0.164 (0.154)	0.142 (0.154)
Unemployment rate	−0.041*** (0.013)	−0.042*** (0.013)
Per capita income	0.089 (0.069)	0.075 (0.070)
State dummies	Yes	Yes
Hospitals	3298	3298
Investment events	1269	1269
R^2	0.1968	0.1994
Log likelihood	−1747.175	−1741.493

Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

coordinate adjustments in complementary activities during the commercialization of the new technology. We link these differences to the relative value that firms using a given organizational form may derive from investing early in the new technology and suggest a correspondence between the organizational form and firms' propensity to invest in a new technology.

We test our arguments in the context of the U.S. health care industry from 1995 to 2006. We explore how hospitals' investments in new imaging technologies are shaped by their form of organization with physicians—key complementors to hospitals. We find that hospitals that pursue alliances with physicians are more likely to invest in new imaging technologies than hospitals that either have an arm's-length relationship with physicians or are integrated and employ their own physicians. We also find that among hospitals pursuing alliances with physicians, the likelihood of investments in new imaging technologies increases with the scope of activities that are jointly carried out by the alliance partners.

Our findings contribute to the literatures on firm boundaries and strategic investments by examining a broad menu of organizational choices that firms pursue to coordinate interdependent activities, and by exploring how firms' organizational form shapes investments in new technologies. While great progress has been made in our understanding of why firms choose a particular organizational form and, more recently, of the implications of such choices for firms' performance (e.g., David and Han, 2004; Parmigiani, 2007; Villalonga and McGahan, 2005), the literature has been surprisingly silent on how the choice of the organizational form may shape firms' strategic investments, an important precursor to firms' performance (Chandler, 1990; Porter, 1980). In contrast, while valuable insights have been generated by scholars focusing on firms' strategic investment decisions in new technologies and considering how they are influenced by economies of scale, the benefits of preempting rivals, and the uncertainty surrounding the returns from such capital investments (e.g., Dixit and Pindyck, 1994; Hall and Khan, 2003; Lieberman and Montgomery, 1988; McGrath, 1997; Reinganum, 1989), these analyses have not considered differences in how firms may be organized within the ecosystem. The results from this study

show interesting linkages between firms' coordination choices and their strategic investment decisions. Hence, on the one hand, the study makes a case to scholars focusing on efficient organizational forms to explore their implications on firms' strategic investments that underlie firms' performance outcomes. On the other hand, it makes a case to scholars focusing on firms' strategic investment decisions to explore the implications of firms' organizational forms that underlie firms' ability to create value from such investments.

The finding that hospitals pursuing alliances with physicians are more likely to invest in new imaging technologies than hospitals pursuing integrated strategies offers some support for an important premise within the firm boundaries literature that there are both costs and benefits of integration (e.g., Gibbons, 2005). While integration provides control over complementary activities and may improve coordination among such activities, it may suffer from reduced incentives, bureaucratic costs, and influence activities (e.g., Grossman and Hart, 1986; Hart and Moore, 1990; Milgrom and Roberts, 1988; Williamson, 1975; 1985). Hence, firms need to consider the cost-benefit trade-offs regarding ownership of complementary activities and evaluate alternative hybrid forms that may provide a better balance between preserving incentives and allowing for coordinated adaptation (Williamson, 1991a). This may especially be the case when human capital is a key resource underlying the complementary activities (e.g., Dyer, Kale, and Singh, 2004; Kapoor and Lim, 2007).

The benefit of the alliance form in facilitating coordination and cooperation between firms and their complementors is confirmed by the result that hospitals pursuing alliances with physicians are more likely to invest in new imaging technologies. The finding that hospitals are more likely to invest in new technologies when their alliances with physicians are characterized by broader scope suggests that besides the 'make, buy, or ally' choice, the design of the alliance may have important implications for interfirm coordination and cooperation. Scholars studying alliances and alliance portfolios within a business ecosystem may build on these findings to explore how the design of the alliance rather than its existence per se may shape firms' value creation and appropriation (e.g., Agarwal *et al.*, 2010; Aggarwal, Siggelkow, and Singh,

2011; Ozcan and Eisenhardt, 2009; Khanna *et al.*, 1998; Oxley and Sampson, 2004).[10]

There is a growing recognition in the strategy field regarding the critical role played by complementors in affecting firms' ability to create and appropriate value (e.g., Brandenburger and Nalebuff, 1996; Eisenmann, Parker, and Van Alstyne, 2006; Teece, 2007). However, there have been relatively few empirical examinations of complementors' interaction with firm strategies (McIntyre and Subramaniam, 2009). This study provides one of the first analyses of how differences in the ways firms are organized with respect to complementors affect their investments in new technologies. In so doing, it adds to the small but emerging empirical literature that has considered the role of complementors in shaping firm strategies and performance outcomes (e.g., Adner and Kapoor, 2010; McIntyre and Subramaniam, 2009, Schilling, 2002; Venkatraman and Lee, 2004). An interesting direction for future research would be to explicitly consider the link between firm's organizational form and the indirect network effects associated with complements (Katz and Shapiro, 1986). For example, in our context, the greater the number and variety of physicians that a given hospital interacts with, the greater the benefits that the hospital enjoys from indirect network effects and the more likely it will be to invest in a new technology. Hence, indirect network effect could be an additional shift parameter within our theoretical framework for the different types of organizational forms. It is quite possible that the magnitude of the 'shift' would be greatest for hierarchies, as firms capture all the returns from indirect network effects whereas the returns are shared in alliances and arm's-length relationships.

While we have taken care in this examination, the study of course has a number of limitations. It is conducted in the context of a single industry, and we are unable to establish the generalizability of our findings across different settings. It will be of interest to see whether our results can be replicated in other contexts and what boundary conditions may be needed to extend the generalizability of our findings. Our focus on medical imaging technologies, while allowing for an examination of a significant technology investment by hospitals, precludes us from making generic assertions about all forms of technology investments. For example, our predictions are based on a key premise that the successful commercialization of technologies requires coordinated adaptation between focal firms and complementors. It is possible that certain types of technologies may not have a direct bearing on complementary activities and therefore will be outside the scope of our predictions. It is also possible that for certain types of technologies, the coordination requirements may be so high—because of greater complexity, newness, or both—that the adaptability benefits of hierarchies may supersede their high organizational costs, so that firms pursuing integrated strategies may be more likely to invest early in such new technologies than firms pursuing alliances. Finally, we are unable to explicitly consider the case of firms choosing to invest in a new technology standard and whether the technology belongs to an open or closed standard (Shapiro and Varian, 1999). We hope that our findings will motivate scholars to study these important types of technological contingencies that may affect the relationship between firms' organizational forms and their strategic investment decisions.

Another important caveat of this study is that we are not implying a correspondence between a firm's technology investment and its performance outcome. We are merely suggesting a correspondence between a firm's organizational form and its propensity to invest in a new technology. Hence, we make no claims that in our or other contexts, alliances are a *superior* form of firm-complementor organization as compared to markets or hierarchies. We expect that the extent to which alliances are superior to other organization forms will be dependent on a number of factors that would include differences between firms' and complementors' business models (Casadesus-Masanell and Yoffie, 2007), firms' alliance capabilities (Kale, Dyer and Singh, 2002), and the nature of technological complexity and change

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[10] The result that hospitals pursuing alliances with physicians are more likely to invest in PET or MRI technology is also consistent with Ciliberto (2006) who found that hospitals using alliances with physicians added more services between 1995 and 1999 than hospitals using arm's-length relationships. He considered a range of services offered by hospitals that include freestanding outpatient care centers, hospital-based outpatient care centers, physical rehabilitation outpatient services, primary care departments, psychiatric outpatient services, alcoholism, drug abuse or dependency outpatient services, breast cancer screening services, diagnostic radioisotope facilities, magnetic resonance imaging, and single photon emission computerized tomography. He also found that hospitals using the integrated mode added more services than the ones using arm's-length relationships.

(Nickerson and Zenger, 2004; Teece, 1996; Kapoor and Adner, 2012). Finally, while we have attempted to address the endogeneity bias that may exist as a result of hospitals' self-selection into the different organizational forms through additional robustness checks, we cannot fully address this possibility.

In conclusion, the study explores how organizational choices with respect to complementary activities affect firms' investments in new technologies. We have argued and shown that differences in organizational forms reflect differences in firms' motivations and abilities to benefit from investing in a new technology. We hope that our results will encourage scholars to explore the link between coordination choices and strategic investments, and to consider such choices in the context of the business ecosystem.

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