Management Science

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

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MANAGEMENT SCIENCE
Vol. 61, No. 6, June 2015, pp. 1197–1216
ISSN 0025-1909 (print) | ISSN 1526-5501 (online)

http://dx.doi.org/10.1287/mnsc.2014.2020

Do Market Leaders Lead in Business Process Innovation? The Case(s) of E-business Adoption

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Are market leaders more likely to be early adopters of business process innovations? Although they tend to enjoy economies of scale in adoption, leaders may find that adjustment costs also increase with scale. Prior work has focused on how misalignment of incumbents' *internal* capabilities may affect their technology strategy. However, technology-capability misalignment may exist *outside* the firm boundary as well. In this paper, I build on mainstream product innovation concepts to predict when market leaders will adopt certain business process innovations. I then test these predictions in a large data set on early e-business adoption, leveraging its novel insight into focal firms, their markets, and their customers. I find market leaders were significantly more likely to embrace new information technology-enabled practices—*except* when customer adjustment costs were a significant concern. These findings highlight the strategic significance of external capabilities in the face of technological change.

Keywords: information technology; innovation; business processes; electronic commerce; firm capabilities; technological change
History: Received February 16, 2011; accepted February 18, 2014, by Bruno Cassiman, business strategy. Published online in *Articles in Advance* January 12, 2015.

1. Introduction

Since the pioneering work of Joseph Schumpeter (Schumpeter 1934, 1942), scholars have repeatedly explored why certain innovations are embraced quickly by market leaders while others are resisted by the most successful incumbents. Market leaders are argued to have the greatest incentives to innovate in many instances (Gilbert and Newbery 1982, Athey and Schmutzler 2001). Yet they may vary in their ability to do so (Henderson 1993, Arora et al. 2009). A principal explanation focuses on the degree of alignment between the nature of the new technology and the competences of incumbent firms (e.g., Tushman and Anderson 1986, Henderson 1993). Misalignment between the demands of new technologies and existing firm capabilities is often blamed for the failure of otherwise healthy firms to maintain their technological—and often competitive—advantage over time.

More precisely, to the extent that capabilities represent "the ability of an organization to perform a coordinated set of tasks, utilizing organizational resources, for the purpose of achieving a particular end result" (Helfat and Peteraf 2003, p. 999), any technology whose development or implementation requires substantially new coordinating processes, new task knowledge, new routines, or new complementary resources will require an innovating firm to invest in closing this "capability gap." The distribution of these gaps is argued to predict not only the diffusion of technology in a market but also patterns of new product introduction, market entry and exit, and firm growth and survival.[1]

Most prior work on incumbent response to technological change has focused on how capabilities *internal* to the focal firm will determine its likelihood of adopting a novel technology. Yet new insights can be gleaned from considering the impact of innovation on a firm's *external* partners and the capabilities they possess (Afuah and Bahram 1995, Afuah 2000). Early on, Abernathy and Clark (1985) touched on some risks for incumbents when innovation demands new knowledge from existing customers.[2] Subsequent work has focused on direct suppliers (Afuah 2001) or suppliers of complements (Adner and Kapoor 2010), with little attention paid to downstream links in the value chain.[3] In contrast, this paper considers, both theoretically and empirically, how adjustment costs for *customers* may affect the behavior of incumbent firms at the onset of technological change.

In another departure from prior research, this study takes place in the context of *business process*

[1] For reviews of this large literature, see Gatignon et al. (2002), Chesbrough (2001), and Danneels (2002).

[2] Christensen and Bower (1990) and Christensen (1997) usefully highlighted the impact that customers have on the rate and direction of incumbent innovation; however, their mechanism focuses on *internal* capability development within firms (Henderson 2006) and not on the distribution of capabilities possessed by customers themselves.

[3] An exception is Afuah (2004).

innovation—a type of innovation that has received limited academic attention despite its growing importance in an increasingly digitized world (Brynjolfsson and Saunders 2010). I begin by developing a framework for predicting whether and when market leaders will pursue new information technology (IT)-based business practices, considering adjustment costs that lie both within the firm boundary ("internal" adjustment costs) and outside it ("external" adjustment costs), with a special emphasis on how gaps between *customers'* existing capabilities and the requirements of new technologies affect leader choices. I then test these predictions in a large multi-industry data set on different types of e-business adoption.

Somewhat surprisingly, I find that market leaders had a disproportionate willingness to adopt different business process innovations—regardless of their *internal* adjustment costs—provided that doing so did not impact customers. However, high-share firms were significantly *less* likely to innovate in their customer interactions across a wide range of settings. Consistent with a causal link between customer capabilities and incumbent technology strategies, this leader reticence was greatly reduced or even reversed in settings where customers' adjustment costs (or their influence) were mitigated.

The research context provides both an opportunity and a challenge for studying the influence of customers' capabilities on the behavior of focal firms. Because they often span firm boundaries, business processes provide a rich setting for observing how interactions between firms yield strategically important outcomes. However, they do not fit easily within existing frameworks. Prior research has focused primarily on product innovation (Cohen and Levin 1989, Gilbert 2006) or, to a lesser extent, innovation in physical manufacturing processes (Dewar and Dutton 1986, Cohen and Klepper 1996, Klepper 1996, Sull et al. 1997). Yet theory and evidence suggest that process innovation may differ fundamentally from product innovation (Utterback and Abernathy 1975, Pisano 1997, Henderson et al. 1998, Adner and Levinthal 2001) and that the drivers of innovation in business or administrative processes may further differ from those for physical ones (Kimberly and Evanisko 1981). The scope for generalizing beyond these familiar contexts has been unclear. This paper provides an opportunity to test and extend existing intuitions in an important but understudied realm of firm behavior.

To do this, I first develop a framework for exploring the costs and benefits of business process innovation and relating them to a share-based definition of market leadership. Although economies of scale will promote adoption by high-market-share firms, the costs of closing the capability gap may also be disproportionately higher for leaders. Many of the relevant mechanisms are well understood for product and physical process innovation (e.g., Tushman and Anderson 1986) but are less so for business processes. In particular, little attention has been paid to how underlying process complexity and impact on customers may condition incumbent behavior. The framework relates these characteristics to costs and benefits for market leaders, generating hypotheses concerning when they will be more or less likely to embrace certain types of business process innovations. In particular, it sets up a tension between internal and external drivers of adoption that can be addressed empirically.

For the empirical tests, I leverage detailed U.S. Census Bureau data on both IT use and salient organizational features for over 34,000 plants across 86 manufacturing industries. I focus on three business process innovations that correspond well to the costs and benefits highlighted in the conceptual framework: Internet-based purchasing (e-buying), Internet-based sales (e-selling), and enterprise resource planning (ERP) adoption. Controlling for a wide range of firm and market characteristics, the results show robust conditional correlations between market share and the likelihood of adoption that vary dramatically by the process in question. Being in the top quartile by market share was associated with a 20% greater likelihood of adopting e-buying, which was a brand-new but low-adjustment-cost innovation at the time. Yet market leaders also had a 48% greater probability of adopting ERP software, despite its notoriously high internal adjustment costs. In contrast, leaders were 36% *less* likely to adopt e-selling. A comparison of e-selling adoption across different market contexts reveals critical heterogeneity in this relationship: in market segments where low competition made it strategically safer to demand adjustment by customers, leader reticence was significantly less pronounced. Similarly, in settings where customer capabilities were less important or better aligned, the lower adoption propensity of leaders was significantly reduced (on the order of 50%) or even reversed.

After exploring potential threats to robustness as well as an array of alternative explanations, I conclude that, contrary to common themes in the literature, market leaders did *not* resist innovating as a result of disproportionately high internal adjustment costs. Instead, their reticence is consistent with misalignment between the demands of the new business technology and the capabilities possessed by their *external* customers. This finding highlights the importance of an often-overlooked constraint on firms' strategic choices: the ability of downstream value-chain partners to embrace technological change.

2. Literature

Internally focused reasons for why market leaders may falter in the face of new technology are richly addressed in prior theoretical work. Firms tend to develop routines (Nelson and Winter 1982) and information filters (Arrow 1974) based on prior experience that condition their reactions to technological change. As firms grow and age, routines are difficult to alter because they become reflected in the technologies and organizational structures used within the firm (Orlikowski 1992). Larger, more-established firms also tend to have invested more in resources (Wernerfelt 1984, Barney 1991) or complementary assets (Teece 1986, Tripsas 1997) based on the old technology. Yet the investments or accumulated know-how that propelled a firm to succeed in the first place may become less valuable under misaligned or "competence-destroying" innovation (Tushman and Anderson 1986). As a result, the most successful firms under the old technology may find adapting to the new one to be too costly.[4]

Despite this wealth of theory, empirical tests have proved challenging. Cohen and Levin (1989) comment on the older body of empirical work by writing, "The most notable feature of this considerable body of empirical research on the relationship between firm size and innovation is its inconclusiveness" (p. 1069). Although more recent studies have made econometric advances (e.g., Blundell et al. 1999), the empirical literature has been criticized overall for failing to account for underlying industry heterogeneity (Cohen and Levin 1989), for confounding product with process innovation (Gilbert 2006), and for abstracting away from relevant organizational capabilities (Cohen 2010). Progress has been made in single-industry settings such as food packaging (Ettlie et al. 1984), footwear manufacturing (Dewar and Dutton 1986), photolithographic alignment equipment (Henderson 1993), mainframe computers (Iansiti and Khanna 1995), and typesetting (Tripsas 1997); however, the feasibility of generalizing beyond these specific contexts remains an open question (Chesbrough 2001). This paper contributes new empirical evidence in a way that accounts for variation in important firm capabilities while spanning a range of industry and firm settings.

Other related streams of work are worth noting. To the extent that business process innovation is difficult to observe, much less imitate, it may confer sustainable competitive advantage on adopters (Barney 1991). In this respect, this paper speaks to a large economics and strategy literature on the competitive implications of technology adoption (see Cohen 2010 for a review). Also, this work contributes to a burgeoning literature on customer participation in innovation (Morrison et al. 2000, Kahl 2007, Baldwin and von Hippel 2011, Chatterji and Fabrizio 2012)—although, customers in this case are also firms. Finally, it relates to a small information systems literature on the adoption of administrative innovations based on new information technology (see Swanson 1994).

[4] They may further face cognitive barriers to even recognizing new technological opportunities (Tripsas and Gavetti 2000, Kaplan and Tripsas 2008).

3. Framework and Hypotheses

3.1. Benefits for Market Leaders: Market Power and Economies of Scale

Building on Schumpeter's original framing (Schumpeter 1934, 1942), much prior research has asked whether market leaders are likely to be the main source of innovative activity in an economy. The effect of market share, per se, on the likelihood of innovation is a central and contentious topic in the economics and strategy literature (Cohn and Levin 1989, Cohen 2010). Much of this prior work focuses on research and development expenditures in the presence of exclusive rights (usually patents) to innovative outputs (Gilbert 2006). However, patents have historically been used less extensively in IT-based innovation (Mann and Sager 2007). In the case of *nonexclusive* rights, firms with more market power are argued to be more likely to innovate because lower competition increases the returns to innovation (Dasgupta and Stiglitz 1980).

Less controversial is the argument that market leaders will enjoy economies of scale in business process innovation. In the absence of intellectual property protection, the primary means of appropriating returns from new discoveries is employing them in a firm's own operations. Note that this is very different for process, as opposed to product, innovation—for processes, the primary user of the innovation is the innovating firm itself. Innovator-adopters with greater market share can spread any fixed costs of developing the innovation across a higher volume of output. Typically applied to innovation in physical processes (e.g., Cohen and Klepper 1996), the logic extends naturally to the business process setting (Kimberly and Evanisko 1981). Thus, in cases where adoption costs do not scale proportionally with firm output,[5] the prediction is that larger producers will enjoy greater net benefits of adoption.

Hypothesis 1. *Market leaders will be more likely to adopt business process innovations, all else being equal.*

3.2. Costs for Market Leaders: Internal and External Adjustment Costs

However, assuming innovation costs to be fixed is problematic. Some or all of the advantage for market leaders may be overwhelmed by adjustment costs

[5] Athey and Schmutzler (2001) provide a theoretical model exploring this issue and show that the positive relationship between market share and adoption of innovations is robust to a wide range of assumptions, with the notable exception of cases where adoption costs are proportional to sales.

that also increase with the scale of production. To understand why this could be, consider the nature of business process innovation in the digital age.

The diffusion of the commercial Internet in the 1990s created an opportunity to transform a wide variety of processes both within and between firms. However, adopters often needed to acquire new capabilities in order to take advantage of frontier technologies. Legacy firm processes often differed dramatically from the "best practices" embedded in the newest software. Existing organizational features (e.g., departmental divisions, employee skills) often did not support the new ways of doing business. Waves of worker retraining, lengthy consulting engagements, and organizational upheaval ensued (Davenport 1993). The magnitude of the change involved is well captured by a popular slogan of the business process reengineering movement of the time: "Don't Automate, Obliterate!" (Hammer 1990).

As a result, the path to achieving technological and organizational alignment was often difficult to foresee and posed significant risks to existing operations, particularly during the early stages of diffusion. The amount of complementary adjustment—or "co-invention" (Bresnahan and Greenstein 1996)—of developing new processes, supporting organizational structures, and enabling IT was difficult to predict and varied widely by firm and by the type of business process innovation the firm was pursuing.

3.2.1. Internal Adjustment Costs and Process Complexity. This variation at the innovation–firm level is important in light of prior arguments that not all technological advances require significant adjustment by all incumbents (e.g., Gatignon et al. 2002). The need for adjustment arises only when an innovation demands substantial new capabilities from the firm. Examples include situations where new technologies demand new coordinating processes (Henderson and Clark 1990), new knowledge or skills (e.g., Dewar and Dutton 1986), new routines (e.g., Henderson 2006), new complementary resources (e.g., Helfat and Lieberman 2002), or even new firm objectives (e.g., Danneels 2004). Innovation becomes costly for incumbents when acquiring new capabilities is more difficult or expensive for more-established firms, or when doing so devalues competencies on which the firm currently relies for its market position (Tushman and Anderson 1986).

For business processes, new knowledge about how to organize a flow of tasks and information—as well as the best complementary technology and practices for supporting that flow—typically comes from outside consultants or from developing substantial new expertise within the firm. Both may be costly, though in different ways. Consultants consume operating budgets and divert internal resources to exchanging and coordinating information. More subtly, an involved consulting engagement can spread propriety knowledge about firm operations to nonemployees, potentially diffusing elements of the firm's "secret sauce." On the other hand, building internal expertise may require more learning-by-doing, which takes time, suffers from a lack of external benchmarking, and may threaten the execution of core firm activities in the short term (Stein 1999).

Both internal and external knowledge acquisition costs will tend to increase in the presence of process complexity. Complexity makes a related group of tasks difficult to both understand and optimize (Wood 1986). Causal ambiguity, which hinders the association of particular processes with particular results (Lippman and Rumelt 1982), increases with complexity (Reed and Defillippi 1990). Furthermore, by definition, complexity entails more interdependencies that can be difficult to manage and coordinate (Simon 1982, Wood 1986, Nickerson and Zenger 2004). Specifically, changes to one business function may require complementary innovation elsewhere in the firm (Milgrom and Roberts 1990, Orlikowski 1992). Interdependencies may entail updates to interprocess linkages as well, threatening the overall "process architecture" in ways that may be particularly risky for incumbent firms.[6]

Thus, although market leaders may be disproportionately more likely to adopt *any* type of business process innovation on average (Hypothesis 1), process complexity may present a situation where the costs of adoption are more likely to overtake the benefits. Moreover, where complexity increases costs in general, it may do so *disproportionately* for large firms. As is well established in prior work, acquiring new skills, adjusting internal task flows and routines, and retasking internal resources all tend to be more difficult for leading incumbents. This is because the well-honed routines of success also engender organizational inertia (Arrow 1974, Hannan and Freeman 1984). Core competencies that conferred competitive advantage in prior years may become "core rigidities" during technology transitions (Leonard-Barton 1992). Most notably, successful incumbents may overallocate internal resources to satisfying existing customers (Christensen and Bower 1990, Christensen 1997) at the expense of developing new technologies. Many of these drivers of incumbent resistance will be exacerbated by process complexity to the extent that it amplifies internal friction and demands more coordination or internal resources to effect change. Thus, the prediction of Hypothesis 1 may be systematically overturned when process complexity leads to substantially higher internal adjustment costs.

Hypothesis 2. *For business process innovations with high* internal *adjustment costs, market leaders will be less likely to adopt, all else being equal.*

[6] Henderson and Clark (1990) develop the argument in a product innovation setting, but the same logic applies here.

3.2.2. Impact on Customers. The prediction of Hypothesis 2 is based on mechanisms that reside entirely within the focal firm. However, a useful feature of new Internet technologies is their ability to transform firm-to-firm interactions. This increases the scope for organizations to benefit from technology in new ways, yet it also increases the costs of adoption along a couple of dimensions that warrant careful attention.

First, consider the baseline operational costs of leveraging IT to innovate in core business processes. At a minimum, any adopting firm must invest in activities such as (1) specifying process requirements, (2) identifying or developing technological solutions, (3) purchasing compatible hardware and software, (4) implementing the technology, and (5) training users (Davenport 1993). Although this is sufficiently challenging for activities that take place within a firm, successful interfirm innovations will require additional external coordination to ensure that information and process flows meet the needs of both business partners. Focal firms will need their customers to invest in communicating and coordinating with them, in addition to possibly giving up modes of interaction in which they have sunk prior technology investments and have existing competence. Existing sales contracts, expectations for performance, and modes of conflict resolution may need to be renegotiated in light of new technological capabilities. Moreover, a focal firm may be one of many suppliers that a given customer must contend with, in which case costs to the customer in question will be even higher.

These interfirm operational challenges are further amplified by the fact that coordinating across firm boundaries is typically more costly than within the firm for a variety of reasons. These include the lack of a "common language" (Arrow 1974), the absence of formal hierarchy (Grant 1996), and a range of transaction costs in exchanging knowledge across firm boundaries (Grant 1996, Nickerson and Zenger 2004). Although these costs apply to all potential adopters (via their customers), they will be disproportionately greater for market leaders simply because they tend to have more customers.[7]

All of this ignores the fact that firms innovating in business processes that impact their customers may face strategic risks that could decrease their net benefits of adoption. To the extent that an innovation requires information, coordination, and other adjustment costs from customers, this will increase the customer's effective price of purchasing from the adopting firm (at least in the short run). This could damage the focal firm's competitiveness if the value of the business process innovation is not perceived by customers to outweigh their own adjustment costs. This type of friction can be thought of as strategic because it will depend on competitive pressure and how much scope the focal firm has to increase its customers' costs of doing business, even temporarily.

These strategic costs may be greater for high-market-share firms for a couple of reasons. Again, a greater number of customers engenders greater challenges: the risk of failure in at least one customer interaction is greater when there are more customers involved. In addition, market leaders will have "more to lose" than smaller competitors if they alienate their customers—i.e., their opportunity costs are greater.[8] In the less common case where market leaders do not have more customers but have instead succeeded by capturing a high sales volume from a smaller number of customers, leaders instead face the problem of monopsony power. In these circumstances, powerful customers can resist adjusting to a new interfirm process flow, hampering successful adoption by the focal firm.

The influence of this combined operational and strategic impact on a leading firm's behavior will depend on how well aligned existing customers' capabilities are with the new technology and business logic. If the alignment is poor, then adjustment costs among customers—i.e., *external* to the firm—may also reduce the net benefits to the focal firm of adopting the innovative business process. Thus, we have the following.

Hypothesis 3. *For business process innovations with high adjustment costs for* external *customers*, *market leaders will be less likely to adopt*, *all else being equal*.

Note that both Hypotheses 2 and 3 describe scenarios whereby the highest-market-share firms resist new business process innovations. The key difference is the locus of the causal mechanism: within versus outside the firm boundary. Moreover, they are not mutually exclusive. The challenge, therefore, is to find an empirical setting with sufficient variation in internal and external adjustment costs to disentangle these conceptually distinct effects.

[7] In the interest of completeness, it may be worth noting that having more customers could, in theory, work in countervailing ways. For instance, more customers could also increase the *benefits* to a market leader from an innovative process that is applicable across all of its customer sites (an economy of scale similar to that explored in Brynjolfsson et al. 2008). These nuances, although theoretically interesting, are beyond the reach of my data. To the extent that having more customers will increase net benefits in this setting, this will work against finding evidence consistent with Hypothesis 3.

[8] It has long been believed that this differential opportunity cost of innovating arising from an existing stream of revenue will disadvantage incumbents (Arrow 1962). However, later work emphasizes that the effect may depend a great deal on the structure of product market competition (Gilbert and Newbery 1982) and has been a source of much theoretical debate (Henderson 1993).

4. Phenomenon: E-business Adoption

The explosion of new business processes enabled by the commercial Internet during the late 1990s offers a rich empirical setting for testing these propositions. Keeping in mind that business process innovation is, in general, quite difficult to observe "in the wild," I use adoption of particular Internet-based business practices to provide a window onto this elusive activity. For this study, I focus on three types of e-business that relate specifically to the margins of firm behavior discussed above.

4.1. E-buying

Some of the most widely known e-business applications of the late 1990s focused on basic—also known as "indirect" or maintenance, repair, and operations (MRO)—procurement. Solutions from vendors such as Ariba and Commerce One enabled online purchasing of materials consumed in the production process but not directly put into finished goods such as lubricant, spare parts, office supplies, etc. This type of procurement centers on spot transactions for largely standardized products. For early adopters of e-buying solutions, implementation typically involved restructuring the internal process flow governing purchase orders, improving access to preapproved vendors, and generating alerts for purchases requiring managerial attention. Although the cost savings from electronic indirect procurement were significant—upwards of 70% per purchase order (Parker 1999b)—it was a relatively straightforward, self-contained activity affecting an organization's cost structure (and not its interactions with customers). Thus, the adjustment costs (both internal and external) were much lower than those for other online activities such as e-selling (Parker 1999b).[9] This makes e-buying a useful base case for testing Hypothesis 1, as it is precisely the type of setting in which economies of scale should dominate.

4.2. Internal Use of Information Technology

E-buying contrasts sharply with another essential facet of e-business diffusion in the late 1990s: the increase in firm investment in *internally focused* applications of IT. Among a wide array of technologies, enterprise resource planning software has received great attention—in part, because of its notorious implementation challenges (e.g., Cliffe 1999, Gattiker and Goodhue 2004). For the purposes of this study, it is important to note that an innovation need not be new to the world to pose challenges for adopters (Rogers 2010). ERP, although not brand-new by 1999, demanded significant process standardization and coordination throughout the firm as well as new capabilities such as IT project management and training (Umble et al. 2003). Although certain affected processes may have been redesigned with a view to better serving clients, the overwhelming focus of ERP implementation has been on integrating internal activities such as accounting, payroll, production planning, etc. It thus represents an example of costly, but nevertheless *internal*, adjustment that is useful for testing Hypothesis 2.

4.3. E-selling

By contrast, early e-selling activities were associated with high internal *and* external adjustment costs according to the framework outlined in §3. To begin, there was no "one-size-fits-all" technology or process to support the new sales approach. Existing software solutions focused primarily on finished goods (e.g., computers, clothing, consumer packaged goods) for sale to distribution partners and customers. The underlying processes that needed to be supported by the new technology varied widely by both industry and firm. According to one analyst report at the time, "What the [e-selling] projects lack in simplicity they make up for with diversity" (Parker 1999a, p. 4).

Because of the diversity and strategic importance of this customer-related business process, the majority of adopters invested in a high level of customization of available software combined with significant business process reengineering (Parker 1999a)—i.e., high co-invention (Bresnahan and Greenstein 1996). A recurring theme among industry observers at the time was the significant time and money required to coordinate all of the necessary software and process changes.[10] Process complexity was explicitly cited as a barrier to wider diffusion of "sell-side" e-commerce solutions (Parker 1999a).

Less mentioned in the popular press—but potentially more salient for understanding incumbents' behavior—was e-selling's impact on customers. To move to Internet-based sales, a firm and its customers needed to collaborate on what the online process should look like, what types of data ought to be exchanged (and how), and where control for certain activities should reside.

[9] Readers familiar with procurement operations may note that this highly standardized indirect procurement process stands in sharp contrast to other common types of procurement. *Direct* procurement concerns the purchasing of highly strategic and often customized parts for use in production. By the late 1990s, however, almost no off-the-shelf software was available to manage direct procurement processes online (Parker 1999a). Solutions for *finished goods* procurement were available; however, they were tailored to the needs of retailers, which lie outside the scope of my data. Thus, e-buying over the Internet at the time of this study was almost exclusively of indirect inputs to production.

[10] Even the notable successes, such as the launch of tool manufacturer Milacron's e-commerce site Milpro.com, were strikingly expensive. The firm spent a dollar in customization and consulting for every dollar of the software license, involved more than 120 people from across the company, and required 10 months to launch (Schultz 1999, Teach 1999).

Not only was this costly and time consuming, but it also typically opened up existing contracts for renegotiation (Davenport 1993). Also, discriminating among customers was more difficult on the open Internet platform compared with older proprietary networks, and required standardization of pricing and bundling strategies across customers and channels. Many firms reported this to be competitively risky, with large incumbents particularly concerned about losing market share or alienating distribution partners (Anderson et al. 2010).

It is important to highlight that these concerns were far more prevalent in business-to-business (B2B) market segments, because B2B transactions typically involve more complicated processes and contractual elements than business-to-consumer (B2C) interactions. Even within B2B, these concerns are distributed unevenly across industries and product markets. For instance, a qualitative study of the apparel industry at the time (Hammond and Kohler 2001) emphasized two distinctive features related to early e-commerce adoption. The first is that apparel firms *and their customers* already shared well-developed standards for characterizing color and fabric in their communications, thus overcoming a significant hurdle to online transactions. Probably related to this, these firms were also accustomed to catalog-based transactions, further easing the transition to e-selling for both buyers and suppliers (Parker 1999a, Hammond and Kohler 2001). My empirical strategy takes advantage of this and other sources of variation in customer-related adjustment costs to test Hypothesis 3 in the context of e-selling (see §§6 and 7).

4.4. Legacy E-business Technology

As a final note on the research setting, although my focus is on frontier Internet-based practices, electronic data interchange (EDI) has existed since the 1970s to allow businesses to electronically exchange documents such as purchase orders and invoices. Because this legacy technology represents a potential substitute for the new processes, I address the potential role played by EDI in the empirical analysis.

5. Methods and Identification

5.1. Empirical Model

To test the three central hypotheses of this paper, I employ a probit model to address the discrete nature of the adoption question. I assume that a particular organization—in this case, a manufacturing plant—will adopt an Internet-based business process innovation if the net benefits of doing so are positive. This approach looks at whether or not adoption has taken place by a particular date and does not model changes in adoption status over time. The implicit behavioral assumption (David 1969) is that plants with higher net benefits of adopting (i.e., returns net of technology and adjustment costs) will adopt first; nonadoption in the cross section signals lower net benefits for the firm from that technology's use.

The most basic estimating equation implied by the theoretical framework in §3 is

$$\begin{aligned}\Pr(BPI_i^j = 1) = \Phi\big(&\alpha + \beta_1 LEAD_i + \beta_2 LEAD_i \times IntCOST_i^j \\ &+ \beta_3 LEAD_i \times CustCOST_i^j + X_i\gamma \\ &+ I_i\delta + \varepsilon_i\big), \qquad (1)\end{aligned}$$

where BPI_i^j indicates whether plant i has adopted a business process innovation affecting process j, $LEAD_i$ is a measure of i's market position that enters both alone and interacted with the two types of adjustment costs, $IntCOST_i^j$ proxies for internal adjustment costs associated with process j at plant i, $CustCOST_i^j$ is an equivalent measure of customer-related external adjustment costs, and X_i represents a vector of plant-specific controls, including measures of IT-related capabilities. Let I_i denote a vector of industry dummies and let ε_i denote a plant-specific error term that is assumed to follow a normal distribution.

Owing to the difficulty of observing continuous measures of internal and external adjustment costs, I rely for my first set of analyses on the institutional features of different business process innovations to define cases where these costs will tend to be particularly high or low across all firms, permitting me to drop them from Equation (1). For instance, following the discussion in §4, e-buying is taken as a case where *IntCOST* is typically negligible and *CustCOST* is zero. Thus Hypothesis 1 in this case concerns whether $\beta_1 > 0$ in the following equation:

$$\begin{aligned}&\Pr(BPI_i^{\mathrm{EBUY}} = 1)\\ &\quad = \Phi(\alpha + \beta_1^{\mathrm{EBUY}} LEAD_i + X_i\gamma + I_i\delta + \varepsilon_i). \qquad (2)\end{aligned}$$

Mapping the process features discussed in §4 onto the core hypotheses from §3, Table 1 summarizes which sign β_i^j is predicted to have in each of the three cases.

High average internal adjustment costs for both ERP and e-selling mean that a cross-process comparison that does not directly measure different types of adjustment

Table 1 **Predictions by Process Type**

Business process	Internal adjustment costs	Customer-related adjustment costs	Prediction
E-buying	Very low	0	$\beta_1^{\mathrm{EBUY}} > 0$ (Hyp. 1)
ERP	High	Low to none	$\beta_1^{\mathrm{ERP}} < 0$ (Hyp. 2)
E-selling	High	High	$\beta_1^{\mathrm{ESELL}} < 0$ (Hyp. 3)

costs cannot distinguish between internal and external adjustment costs as a possible driver of leader behavior. Ideally, there would exist a business process innovation that had, across the board, very high external adjustment costs but low internal ones. This would provide a clean contrary prediction to the e-buying case and help pin down the differential effect of internal versus external factors.

As no such process exists in the data—nor in the world, to my knowledge—I also leverage variation *within e-selling* in customers' adjustment costs across different markets and geographies to help identify which types of costs have the greatest empirical salience. To see whether customer costs do indeed moderate the response of market leaders, I control for organizational characteristics that will cause firm-level variation in internal adjustment costs (see §§5 and 6) and explore the following relationship:

$$\Pr(BPI_i^{\text{ESELL}}=1) = \Phi\big(\alpha + \beta_1^{\text{ESELL}} LEAD_i + \beta_2^{\text{ESELL}} LEAD_i \times CustCOST_i + X_i\gamma + I_i\delta + \varepsilon_i\big). \tag{3}$$

As customer costs go down (up), Hypothesis 3 predicts that β_2^{ESELL} will be greater than (less than) 0.

5.2. Identification

My research design relies on several strategies to identify the relationship between market position and innovation across these different process contexts. The first is to use an unusually rich set of controls for other factors that might drive the results. For example, prior research finds strong correlations between IT adoption and the number of employees and firm age (Forman and Goldfarb 2006) as well as complementary skilled labor (Bresnahan et al. 2002); high-quality measures are available in the Census Bureau's data. Next, I address unobserved effects arising from specific industry contexts, potentially including product market competition, by including a large set of industry dummies at a relatively granular level.

From a statistical standpoint, identification in this model requires that market share and other explanatory variables not be simultaneously determined with adoption (Gilbert 2006). Prior work on IT in organizations has commonly relied on the argument that IT decisions vary on a shorter timescale than do organizational choices, and they are therefore quasi-fixed in the short run (e.g., Bresnahan et al. 2002). Although this argument could be made here, I also directly address simultaneity concerns by relying on values for all non-IT explanatory variables that are lagged by two years (to 1997). However, the lack of panel data makes it impossible to control for unobserved firm characteristics in the conventional ways.

My next strategy leverages the ability to observe adoption by the same firm at the same time to innovations that are similar in many of their investment requirements (new hardware, new software, IT consulting, etc.) but that vary specifically in the types of co-invention discussed in the framework—in particular, the customer dimension. The advantage of this approach is the ability to better control for potentially confounding influences such as an unobserved firm-specific "taste" for technology. In particular, I check the robustness of my findings with a bivariate probit model that accounts for unobservables that may influence the choice of more than one business process innovation at a time. Because a firm that is disproportionately likely to adopt *any* kind of new IT will bias the bivariate probit results toward adoption of *both* business process innovations (or vice versa), the difference in leadership effects between the two technologies identifies how market leaders respond to high- versus low-co-invention business process innovations.

Finally, I use variation in customers' capabilities and their importance to the focal firm within a single process innovation—specifically, e-selling—to identify the impact of customer adjustment costs on market leader behavior (discussed in more detail in §6.5). To address the possibility that decisions for plants within the same firm may be correlated, all standard errors are clustered at the firm level.

6. Data

6.1. E-business Adoption

The dependent variables capturing different business uses of IT come from the Computer Network Use Supplement (CNUS) included in the U.S. Census Bureau's 1999 Annual Survey of Manufactures (ASM). The over 34,000 plants in the sample account for more than 50% of manufacturing employment and output in the United States (Atrostic and Nguyen 2005). They belong to more than 20,000 firms in 86 different industries, providing data across a wide range of market contexts. Establishments are weighted according to their likelihood of appearing in the size-stratified sample, permitting estimation of population statistics for the roughly 400,000 manufacturing plants across the United States.

The CNUS contains detailed information on plant adoption of a variety of e-business practices and other related technologies. In particular, plants identify whether or not they place or accept orders over a network and whether the primary network for doing so is the Internet. Establishments that report making purchases primarily over the Internet are coded as having adopted e-buying, similarly for e-selling.[11] Plants

[11] A useful feature of this definition is that it excludes establishments that might merely be experimenting with Internet-based processes while still relying primarily on a different network (such as an intranet, extranet, or EDI) for its online transactions.

Table 2 Estimated Adoption of E-business in U.S. Manufacturing, 1999

E-business practice	% of plants in population (estimated)
Place orders online over the Internet (e-buy)	21
Accept orders online over the Internet (e-sell)	15
Place OR accept orders over the Internet	30
Place AND accept orders over the Internet	7
ERP	15

also report whether or not they have adopted "fully integrated" ERP software.

Based on this snapshot, diffusion is broad, with e-buying and e-selling taking place in every subsector and across the size distribution. Yet it is not deep (see Table 2): the e-buying adoption rate is only 21% and e-selling only 15%. Integrated ERP adoption is similarly low, at only 15% of the population.

These high-level summary statistics mask a great deal of heterogeneity across industries in the use of network technology. For instance, computers and electronic products (North American Industry Classification System (NAICS) 334) and printing (NAICS 323) industries have the highest penetration. In the former, 38% of plants place orders and roughly 21% accept orders over the Internet; in the latter, the percentages are 32% and 34% for e-buying and e-selling, respectively. Apparel manufacturing (NAICS 315) is a trailing industry on average with around 7% for both e-buying and e-selling. Some industries lean considerably more toward one e-business practice than the other. Only 6% of textile product mills (NAICS 314) place Internet-based orders, but over 16% accept them (see Table 6 in §7 for more industry-level statistics).

Another important difference between e-buying and e-selling in the data concerns the fact that the activities captured by the survey do not represent mirror images of the same set of transactions. The suppliers of MRO goods to manufacturing plants are not manufacturing firms themselves but wholesale and retail outlets that sell a range of MRO products (e.g., Office Depot for paper and pens, Grainger for lubricants and batteries). Thus, the supplier side of the e-buying transaction is not included in the CNUS's manufacturing-based survey frame. Likewise, the distributors, wholesalers, and retailers who make up the customer side of the e-selling transaction for many firms also lie outside the manufacturing sector. Thus, the e-buying and e-selling activities in this study concern completely separate transactions (though not necessarily independent investment decisions, which I address in the econometrics).

6.2. Market Leadership

The primary explanatory variable for this study is market share of the focal plant. I leverage the complete 1997 Census of Manufactures (CMF)[12] to measure the total value sold in each industry[13] and use it to calculate the share of total value shipped by each establishment. This value is logged to address the skewness of its distribution.

6.3. Drivers of Internal Adjustment Costs

Market leadership may be correlated with organizational features that also impact the adjustment costs of business process innovation. For instance, a firm that needs to coordinate across more locations may have geography-based costs that interact with—but are conceptually orthogonal to—the costs and benefits arising from the sheer scale of its output. Similarly, vertically integrated commodity flows within a firm may entail a greater need to coordinate the processes governing these transfers (McElheran 2014), yet vertically integrated firms also tend to be more successful (Atalay et al. 2014).

To control for these and other potentially confounding factors, I rely again on the complete 1997 CMF to observe all of the manufacturing plants belonging to the parent firm, even if they are not in the CNUS sample. This makes it possible to accurately calculate the number of plants belonging to the same parent firm. In addition, the ASM provides data on the value of shipments to other establishments within the firm for further assembly, fabrication, or manufacture. Because this only tracks outbound transfers to other locations within the firm (thus underestimating the extent of vertical integration for plants that receive inbound transfers), I sum up the total value of internal transfers across plants within the firm.

6.4. IT Capabilities

A crucial insight from prior research is that market leaders may, in fact, possess important capabilities that are well aligned with a particular technological advance. This may actually lower adjustment costs for the most successful firms (e.g., Tushman and Anderson 1986). In the case of IT-based business process innovations, a central consideration is how sophisticated a firm is in its knowledge and use of IT, in general. A firm that has historically invested in IT, that hires employees with IT-related skills, and that has an up-to-date infrastructure that integrates easily with next-generation technology will have significantly lower costs of selecting, adapting, and implementing new IT-based business processes (Attewell 1992, Fichman and Kemerer 1997). Although these capabilities are likely to reduce co-invention costs

[12] Conducted every five years by the U.S. Census Bureau, this census captures the value of all shipments from nearly all manufacturing plants in the country; response is required by federal statute and quality-checked by the Census Bureau.

[13] I define the relevant market by the four-digit NAICS code reported as the primary product for each plant of interest.

for firms of all sizes, larger firms are more likely to have significant prior IT investments (Forman and Goldfarb 2006) and specialized employees (Dewar and Dutton 1986).

On the other hand, prior IT investments may increase the costs of adopting new technologies by imposing switching costs on prior-generation IT leaders (Klemperer 1995, Forman 2005). Because they tend to have enjoyed economies of scale in the past, leading incumbents are more likely to have invested in incompatible legacy systems.

The implications of these observations are twofold. The first is that controlling for prior IT capabilities is essential for identifying the effects of interest. The second is that the expected influence of IT-based capabilities is, in general, ambiguous and depends critically on the type of IT in use at the firm.

For these reasons, I explore various measures of IT-related capabilities derived from the CNUS. Because this is the exclusive source of IT adoption information in the data, lagged measures of IT investment are unavailable. My preferred measure is an indicator of whether or not the plant has invested extensively in IT for use in its internal production processes, as this is likely to pick up a degree of "IT savvy" while being less codetermined with the e-buying and e-selling innovations. This measure of intensive use of internal IT is equal to 1 if the plant reports using networked computers in two or more of the following: design of the production process, production scheduling, production monitoring, and test and acceptance of product. The adoption rate of this margin of IT use is comparable to that of e-selling at roughly 13% of the population. Other measures I explore include legacy EDI technology (14% adoption rate), local area networks (or LANs) (47% adoption rate), and the presence of fully integrated ERP software (15% adoption rate). This last I explore separately as a business process innovation in its own right.

6.5. Impact on Customers

Since I lack data on specific firm-to-firm linkages (and hence the capabilities of specific customers), my approach to testing Hypothesis 3 relies on several sources of variation in the degree and importance of customers' adjustment costs. First, I exploit variation between the processes themselves—in particular, the sharp difference in the external demands of e-buying versus e-selling, for which there is rich anecdotal evidence (see §4). I also compare e-selling to ERP adoption to keep the internal adjustment costs comparably high across process types while again exploiting a contrast in external coordination costs.

Next, I focus attention exclusively on e-selling adoption, exploiting market-based variation in the extent to which potential adopters might be able to impose additional adjustment costs on their customers without incurring strategic penalties. Assuming that increased competition reduces the scope that manufacturers have to demand complementary business process innovation from their business partners, I construct a Lerner index of competitive pressure by industry. Following prior work (e.g., Aghion et al. 2005), I rely on a ratio of profits to sales, specifically, $1 - (\text{sales} - \text{cost of materials} - \text{wages})/\text{sales}$. A higher Lerner index is assumed to represent a greater level of product market competition (and hence lower margins). To avoid bias caused by short-term market fluctuations or empirical outliers, I take the value-weighted average of this measure for each industry over the past 10 years, where industry is defined as a four-digit Standard Industrial Classification (SIC) code.[14]

Next, I leverage industry variation in whether an e-selling transaction is likely to be primarily B2B or B2C. The latter type of customer linkage is defined in the data by relying on the U.S. Bureau of Economic Analysis' (2012) input-output tables to identify industries where 75% or more of the value in that industry is transferred to "final use" by consumers.

Although a detailed industry-by-industry analysis is beyond the scope of this paper, I exploit the considerable sample size to include a large number of industry-fixed effects in all core specifications and also to estimate industry-level regressions (see Table 6 in §7). The latter is useful for exploring whether the qualitative evidence available for the apparel industry (see §4) is consistent with observed patterns in the data. For industry affiliation, I rely on the Census Bureau's designation, which is based on the six-digit NAICS product code in which the plant ships the greatest value of output; I aggregate up to the four- and three-digit levels to facilitate estimation and interpretation of the results.

Finally, but perhaps most importantly, I take advantage of another detailed Census Bureau data source to observe variation in the IT-related capabilities of the focal establishment's customers. The Commodity Flow Survey (CFS) conducted in 1997 tracks the destinations of a representative sample of shipments from the U.S. manufacturing sector (among others). Although this unique data set does not shed light on particular firm-to-*firm* linkages, it does identify firm-to-*location* linkages.[15] This makes it possible to exploit geographic variation in the "IT savviness" of customers, albeit at an aggregated level.

[14] The Census Bureau shifted from using the SIC to the NAICS classification in 1997, so SIC is used for consistency.

[15] Atalay et al. (2014) described these data in depth and discussed their value for measuring commodity flows between establishments in the U.S. economy. The overlap with my sample is over 12,000 establishments; see Table 5 in §7.

Table 3 Definitions, Population Means, and Standard Deviations of Variables

Variable name	Definition	Estimated mean[a]	Estimated SD
E-sell	= 1 if the plant reports selling primarily over the Internet; = 0 otherwise	0.146 (0.004)	0.353
E-buy	= 1 if the plant reports buying primarily over the Internet; = 0 otherwise	0.213 (0.004)	0.410
Intensive internal IT	= 1 if the plant reports using networked computers in two or more of the following: design of the production process, production scheduling, production monitoring, and test and acceptance of product; = 0 otherwise	0.134 (0.003)	0.340
ERP	= 1 if the plant reports having a fully integrated enterprise resource planning application; = 0 otherwise	0.152 (0.003)	0.359
EDI	= 1 if the plant reports having electronic data interchange technology; = 0 otherwise	0.144 (0.003)	0.351
LAN network	= 1 if the plant reports having a local area network; = 0 otherwise	0.469 (0.005)	0.499
Market share	Logged share of total value shipped in 1997 by all plants in the focal plant's primary NAICS4 code	−7.94 (0.019)	1.64
Share catalog w/customers online	= 1 if the plant reports providing product descriptions or catalog information online (over any kind of network); = 0 otherwise	0.092 (0.003)	0.289
Number of plants	Total number of manufacturing plants belonging to the same parent firm in 1997	7.51 (0.006)	22.2
Within-firm transfers	= 1 if the estimated value of goods and services shipped to other establishments within the same firm is greater than 0; =0 otherwise	0.131 (0.002)	0.337
Age < 10	= 1 if the plant is 10 or fewer years old; =0 otherwise	0.287 (0.005)	0.453
Skill mix	Share of nonproduction worker wages to total salaries and wages in 1997	0.375 (0.002)	0.185
Low competition industry	= 1 if the plant's primary industry has a weighted 10-year average Lerner index below the sample mean; = 0 otherwise	0.440 (0.005)	0.496
B2C industry	= 1 if the plant's primary industry has 75% or more of value going to "final use" according to the U.S. Bureau of Economic Analysis input-output tables; = 0 otherwise	0.086 (0.003)	0.271
Customer IT sophistication	Shipment-value-weighted average of the estimated adoption of intensive internal IT in the counties to which the plant ships output	0.143 (0.001)	0.052

[a]Standard errors are in parentheses. Means and standard deviations represent population moments estimated using the U.S. Census Bureau sampling weights.

To do this, I first use the CFS to determine the counties to which each focal plant ships its output. Since the goal is to calculate the relevant IT-related capabilities *of customers*, I flag for removal each instance of a plant shipping to the same county in which it is located so that the final measure is not contaminated by own-IT adoption choices. I then use the CNUS and Census' sample weights to estimate population counts of plants that report intensive internal use of IT (described in §6.4) by county. Because some counties are sparsely populated, I restrict attention to counties with five or more plants in the CNUS. Finally, I create a *plant-specific index of customers' capabilities* by purging population adoption counts of the focal plant, taking average adoption rates by county, and calculating the shipment-weighted average of IT adoption across all counties to which the focal plant ships output. This weighted average adoption of IT by customers is still quite low at only 14%, but it is consistent with the adoption rates of other enterprise software in the sample. Variable definitions and estimated population means and standard deviations are provided in Table 3.

7. Results

7.1. Cross-Process Comparisons

Table 4 reports the raw coefficients from probit estimations of the likelihood of adopting the IT-enabled business process innovations discussed above. To facilitate interpretation of the findings, marginal effects (calculated at sample means) for the market share variable and for an indicator of whether the plant is in the top quartile of the market share distribution are reported in the last two rows of the table.[16] Column (1) reports the basic conditional correlation of

[16] Marginal effects are calculated using the *margins* command in Stata 13.

Table 4 Probit Analysis of the Likelihood of Business Process Innovation: E-buying, E-selling, and ERP Adoption

	(1) E-buy	(2) E-sell	(3) E-sell (IT controls)	(4) E-sell (Org. controls)	(5) ERP
Market share	0.130***	−0.074***	−0.071***	−0.044***	0.256***
	(0.010)	(0.013)	(0.014)	(0.015)	(0.015)
Number of plants (in 10's)				−0.028***	−0.024***
				(0.008)	(0.008)
Within-firm transfers				−0.269***	0.174***
				(0.050)	(0.051)
Intensive internal IT			0.318***	0.337***	0.718***
			(0.047)	(0.047)	(0.040)
EDI			−0.396***	−0.380***	0.444
			(0.049)	(0.049)	(0.034)
Age < 10	0.145***	−0.018	−0.023	−0.019	0.048
	(0.037)	(0.043)	(0.043)	(0.043)	(0.038)
Skill mix	0.215***	0.330***	0.346***	0.277***	0.412***
	(0.078)	(0.088)	(0.089)	(0.090)	(0.093)
Industry controls	Yes	Yes	Yes	Yes	Yes
N	34,582	34,582	34,582	34,582	31,319
Pseudo R^2	0.0518	0.0762	0.0863	0.0905	0.2358
Marginal effects					
Log market share	0.037***	−0.015***	−0.015***	−0.010***	0.045***
	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)
Belonging to top market share quartile	0.085***	−0.085***	−0.079***	−0.052***	0.073***
	(0.006)	(0.007)	(0.007)	(0.007)	(0.005)

Notes. Weighted maximum-likelihood probit estimation shown, reporting raw coefficients. Observation weights are provided by the U.S. Census Bureau to estimate population statistics for the entire manufacturing sector (roughly 400,000 plants in 1997). The last two rows report marginal effects of logged plant market share and of being in the top quartile of the market share distribution, calculated at sample means using the *margins* command in Stata 13. Industry controls are indicators of the plant's primary four-digit NAICS code. Some data for ERP adoption are missing in the 1999 CNUS survey, causing a change in sample size in column (5). Robust standard errors are clustered by firm and included in parentheses.

*Statistically significant at 10%; **statistically significant at 5%; ***statistically significant at 1%.

e-buying adoption with logged market share, including a parsimonious set of controls for age, employee skill mix, and the plant's primary industry classification (four-digit NAICS). It reveals a significant positive relationship between market leadership and the likelihood of adopting e-buying. Consistent with Hypothesis 1, market leaders are significantly more likely to adopt this relatively low-cost business process innovation. In this sparse model, the marginal effect for being in the top 25% of firms (see bottom row) is 8.5 percentage points—a 40% increase over the average adoption rate in the population. A specification with the full set of controls (available upon request) reduces this estimate to 4.3 percentage points—still an economically significant increase of 20%.

Column (2) shows that this relationship is completely reversed for e-selling. Market leadership and the likelihood of e-selling are negatively correlated at the 1% significance level. The marginal effect of market leadership in this specification is a negative 8.5 percentage points. Based on a lower average adoption rate of e-selling, this represents a striking 58% lower likelihood of adoption. Column (3) includes controls for other IT adoption at the plant that could bias the e-selling estimates; both are significant, though with opposite signs. Internal IT is positively associated with e-selling adoption. EDI appears to substitute for the newer Internet-based transaction. Because these countervailing effects are included together, the point estimate for market leadership remains almost unchanged, as does the marginal effect of −0.079 (bottom row).

As discussed in §6, a central concern for identifying the effect of firm scale is that market leadership may be correlated with organizational features that also impact the returns to business process innovation. For example, *organizational* (as opposed to process) complexity may also increase as a firm grows, driving up internal adjustment costs at the same time that benefits increase. Column (4) suggests that this is a legitimate concern. When controls are included for the number of plants throughout the firm and for being in some measure vertically integrated (i.e., having within-firm transfers), the raw point estimate for the market share variable rises to −0.044, which is significantly different from the value in column (2) at the 1% level. The magnitude of the top-quartile marginal effect drops to 0.052 percentage points, suggesting that, although the relationship is still negative, market leadership is associated with only a 36% lower likelihood of e-selling when organizational complexity is separately addressed.

This pattern of results is, thus far, consistent with both Hypotheses 2 and 3. The e-selling process, which entails greater internal and external adjustment costs, is empirically far less prevalent among leading firms. Column (5) provides the first piece of evidence of an external driver of this result: a very strong *positive* correlation between market share and the likelihood of ERP adoption. The top quartile of establishments is 48% (taking the marginal effect of 0.073 in the bottom row over the average adoption rate of 0.152) more likely to adopt than the lagging counterparts in their industries. Given the notoriously high internal adjustment costs associated with ERP (see §4), this is problematic for Hypothesis 2, and it suggests that economies of scale can still dominate firm decision making for IT-based innovations even when internal adjustment costs are very high.

7.2. Cross-Market Comparisons

Because e-selling and ERP may not be perfectly comparable in their levels of internal adjustment costs—and because other things may vary on the margin between the two business process innovations—Table 5 restricts attention only to e-selling adoption. Instead, it exploits variation across market settings to study the extent to which external adjustment costs may be driving observed firm behavior.

7.2.1. Competitive Pressure. The ideal way to test whether customer impact is driving the observed adoption patterns would involve a direct measure of particular capabilities possessed by customers related to the new online transactions. Lacking data on individual customers of the plants in my data set, I take advantage of industry-level variation in customer impact to gain insight on this relationship. First, I explore variation in the scope that firms have to demand complementary investments in process change from their customers.

Because this set of analyses explicitly uses industry characteristics (rather than controlling for them), I omit the industry-fixed effects included throughout Table 4. To facilitate comparisons across tables, therefore, column (1) of Table 5 simply reports the results of the baseline e-selling specification but omitting the 86 industry controls. It is worth noting that industry variation is important for predicting leader behavior: omitting these fixed effects magnifies the negative correlation with market share. The marginal effect in this specification is −0.023 versus −0.010 in column (4) of Table 4.

Column (2) of Table 5 interacts the market share measure with an indicator of whether the focal plant is in a "high competition" or "low competition" industry, where the cutoff between the two categories is the mean Lerner index value. Lower competition is associated with a significantly greater likelihood of adopting e-selling. More to the point, lower competition significantly increases the observed propensity of *leaders* to adopt e-selling. Not only is the interaction term positive and significant at the 5% level; the magnitude of this effect is large: the marginal effect averaged over plants in "high-competition" industries (see lower section of the table) is −0.028, whereas that for "low-competition" industries is only −0.017. The difference between these estimates is significant at the 4% level and is even more pronounced in a model where all covariates are interacted with the competition indicator (available upon request). These results are robust to different cutoffs for the low versus high categories as well as different approaches to calculating the Lerner Index (e.g., 5-year versus 10-year means or industry medians versus means). Overall, this pattern is consistent with the market leader penalty being significantly reduced in contexts where firms have more scope to demand complementary investments from their customers without incurring strategic penalties.

7.2.2. B2B vs. B2C. Although reduced competitive pressure may reduce risks for market leaders whenever a significant customer investment is required, another way to reduce external adjustment costs is to require less investment in the first place. Based on this logic, I next explore the distinction between B2C and B2B transactions. Not reported here, a simple model that interacts logged market share with an indicator of whether the plant is in a predominantly B2C industry[17] yields a positive coefficient that is significant at the 1% level (results available upon request). More notably, the marginal effect of logged market share averaged across the B2C establishments completely shifts signs. Although the calculated effect in this specification is not significant at conventional levels, the difference between the B2B and B2C segments is significant at better than 1%. Reported in column (3) of Table 5, a model that interacts *all* of the covariates with the B2C indicator yields an average marginal effect of 1.1 percentage points—a 7% *increase* in the likelihood of e-selling adoption—that is significant at the 6% level. To the extent that the B2C versus B2B distinction captures variation in the demand for external co-invention, these results support Hypothesis 3.

7.2.3. Apparel Case Study. Column (4) of Table 5 reinforces the interpretation that market leader adoption of e-selling was deeply affected by how much the innovation demanded of customers. An industry-by-industry analysis based on NAICS3 classifications

[17] As described in §6, B2C is defined here as 75% or more of value in that industry going to "final use" according to the U.S. Bureau of Economic Analysis (2012). These results are robust to increasing the threshold up to 90%; however, lowering the threshold generates a great deal of noise in the estimates.

Table 5 Customer Impact on Business Process Innovation: Industry- and Plant-Level Variation in E-selling

	(1) E-sell (No industry controls)	(2) E-sell (Competition interaction)	(3) E-sell (B2C interaction)	(4) E-sell (Apparel)	(5) E-sell (Customer IT capabilities)	(6) E-sell (Less urban)
Market share	−0.105***	−0.123***	−0.116***	0.201***	−0.208***	−0.563***
	(0.013)	(0.016)	(0.013)	(0.007)	(0.061)	(0.105)
Low competition industry		0.419**				
		(0.192)				
Low competition industry × *Market share*		**0.046****				
		(**0.022**)				
B2C industry			1.62***			
			(0.359)			
B2C industry × *Market share*			**0.179*****			
			(**0.039**)			
Customer IT sophistication					5.35**	18.28***
					(2.75)	(4.22)
Customer IT sophistication × *Market share*					**0.737****	2.44***
					(**0.375**)	(0.571)
Plant and firm controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry controls	No	No	No	No	Yes	Yes
N	34,582	34,582	34,582	797	12,390	2,561
Pseudo R^2	0.0395	0.0402	0.0427	0.1079	0.1086	0.2201
Marginal effects						
Market share[a]	−0.023***			0.023***		
	(0.003)			(0.007)		
Market share across high competition industries[b]		−0.028***				
		(0.004)				
Market share across low competition industries[b]		−0.017***				
		(0.004)				
Market share across B2B industries[b]			−0.027***			
			(0.003)			
Market share across B2C industries[b]			0.011*			
			(0.006)			
Market share at 10%ile of customer IT[a]					−0.022***	−0.057***
					(0.011)	(0.011)
Market share at 90%ile of customer IT[a]					−0.010*	−0.008
					(0.009)	(0.009)

Notes. Weighted maximum-likelihood probit estimation shown, with weights provided by the U.S. Census Bureau to estimate population statistics. All specifications include controls for within-firm transfers, the number of plants at the parent firm, intensive use of internal IT, and EDI adoption. Robust standard errors are clustered by firm and included in parentheses. Column (5) has fewer observations as a result of the restriction that customer counties have five or more plants as well as some data loss in matching the 1997 Commodity Flow Survey with the 1999 CNUS. Industry controls are indicators of the plant's primary four-digit NAICS code. The lower half of the table reports marginal effects calculated using the *margins* command in Stata 13.

[a]Marginal effects at means of other covariates.

[b]Marginal effects averaged across subsets of the sample.

*Statistically significant at 10%; **statistically significant at 5%; ***statistically significant at 1%.

(see Table 6) yields conditional correlations between logged market share and e-selling adoption that are nearly always negative (though not always statistically significant—see the last column in Table 6). The apparel manufacturing industry (NAICS code 315) stands out, however, in that the coefficient is not only *positive* but also both economically and statistically significant: the marginal effect of logged market share is 2.3 percentage points (column (4) of Table 5) compared with a baseline industry adoption rate of 6.7%.[18] In other words, although *average* industry adoption was relatively low, *leaders* were significantly more likely to be at the forefront of new IT-enabled sales practices.

Rather than being an anomaly, apparel may be the "exception that proves the rule" governing how customers' capabilities influence patterns of innovative activity. As mentioned previously, Hammond and Kohler (2001) detailed the advantages that apparel firms had compared with those in other industries where communications were less standardized and catalog-based sales less prevalent. A detailed assessment of the readiness of every industry's customers to move to online transactions lies beyond the scope of this paper; however, the coincidence in this case of a distinctive

[18] The results for apparel are robust across a range of specifications. Depending on the specification, other industries with a positive coefficient for logged market share may be nonmetallic minerals, primary metals, forging and stamping, and furniture.

Table 6 Industry-Level Adoption and Market Leadership Coefficients

NAICS code	Industry	*N*	% e-buy (estimated)	% e-sell (estimated)	Probit coefficient for logged plant market share: E-buy	Probit coefficient for logged plant market share: E-sell
311	Food	2,900	18.6	8.3	0.143***	−0.116*
312	Beverage and tobacco	370	22.8	12.0	0.149**	−0.066
313	Textile mills	688	15.9	11.1	−0.109	−0.416***
314	Textile product mills	440	6.1	16.4	0.355***	−0.164
315	**Apparel**	**797**	**7.6**	**6.7**	**0.207*** **	**0.201*** **
316	Leather and allied products	161	17.4	20.5	−0.033	0.033
321	Wood products	1,947	12.8	7.7	0.077	−0.144**
322	Paper	1,477	20.5	11.9	0.092**	−0.036
323	Printing and related support activities	1,980	32.0	34.2	0.108***	−0.076*
324	Petroleum and coal products	499	16.1	2.9	Omitted due to disclosure restrictions	
325	Chemicals	2,374	22.5	12.0	0.060	−0.059
326	Plastics and rubber products	2,349	25.0	13.6	−0.022	−0.083
327	Nonmetallic mineral products	1,858	12.0	5.6	0.202***	0.097**
331	Primary metal	1,136	24.6	10.1	0.073	0.070
332	Fabricated metal products	5,286	18.7	13.1	0.131***	0.036
333	Machinery	3,470	25.3	16.5	0.105***	−0.055
334	Computer and electronic products	1,693	37.9	21.1	−0.028	−0.028
335	Electrical equip., appliance, components	977	27.2	13.9	0.103**	−0.196**
336	Transportation equipment	1,562	25.7	12.4	−0.016	−0.160**
337	Furniture and related products	1,159	16.2	8.5	0.042	0.101
339	Miscellaneous	1,459	24.1	18.5	0.101**	−0.024

Notes. Case study industry is in bold. Record counts, estimated population adoption, and probit coefficients from weighted maximum-likelihood probit estimation are reported by three-digit NAICS code. All specifications include controls for the number of plants at the parent firm, within-firm transfers, intensive use of internal IT, EDI adoption, age, and employee skill mix. Robust standard errors are clustered by firm and included in parentheses.

*Statistically significant at 10%; **statistically significant at 5%; ***statistically significant at 1%.

technology-capability alignment and an unusual positive propensity of market leaders to adopt stands out sharply in the overall results and is consistent with the mechanisms proposed for Hypothesis 3.

7.2.4. Geographic Variation in the IT Sophistication of Customers. My final approach to testing Hypothesis 3 relies on plant-level variation in customers' capabilities related to the e-selling process innovation. Column (5) of Table 5 interacts logged market share with the average IT sophistication of the plant's customers.[19] Having more-sophisticated customers with respect to IT unsurprisingly augments the likelihood that *any* firm will adopt e-selling. Most importantly for the purposes of this paper, having more-capable customers significantly increases the likelihood that *leaders* will adopt: the interaction term is positive and significant at the 5% level. To get a sense of the magnitude of this effect, in the lower panel of Table 5, I compare the marginal effect of market share at the 10th percentile of the customer sophistication measure to that at the 90th percentile: the former yields an estimate of −0.02 percentage points, whereas the latter yields only −0.01. There is still a "leader penalty" in terms of how likely the highest-market-share firms are to adopt e-selling; however, its magnitude is halved when customers' capabilities are substantially greater (and adjustment costs commensurately lower). These estimates are significantly different from each other at the 5% level and are present for less-extreme comparisons (e.g., the 25th versus the 75th percentile). At the top of the customer capability distribution, the point estimate actually becomes positive, although it is noisy (available upon request). I further restrict attention to plants in less-urban areas[20] to isolate establishments that may be disproportionately dependent on their value chain partners because of lower local agglomeration. This restriction increases the magnitude and precision of the result (see column (6) of Table 5). In fact, the marginal effect of market share at the 99th percentile of the customer capability distribution for this subset of firms is 0.049 (a 33% *increase* in e-selling likelihood) and is significant at the 1% level (available upon request).

7.3. Robustness Checks

These findings are robust to a range of variations in the analysis. For instance, alternative definitions of market leadership, including market share of the parent firm, logged plant sales, logged plant profits, and size

[19] Technically, the sophistication of the locations in which the plant has customers; see §6.5.

[20] Specifically, in metropolitan statistical areas with populations less than 500,000.

measured by the total number of employees yield substantively similar results. The findings are also unchanged for alternative measures of organizational complexity, including diversification across product markets and dispersion across metropolitan areas, as well as substituting LAN or ERP adoption for the intensive internal IT measure. Using industry controls at the NAICS6 level yields similar results, as well.

Given the cross-sectional nature of the data, one threat to identification is unobserved heterogeneity among plants that could generate the same patterns for reasons unrelated to the capabilities of customers. For instance, even within narrow market segments, firms may vary greatly in the extent to which they standardize their product offerings and/or pricing schedules. As already mentioned, firms already employing a catalog-based sales process were anecdotally much better positioned to adopt e-selling (Parker 1999a, Hammond and Kohler 2001). If larger firms tended to have less-standardized sales processes or product offerings, this could generate the same observed pattern in the data (or, if more-standardized, this would cause the estimates to be smaller than what they ought to be). Interestingly, plants report separately in the CNUS whether or not they share catalog information online with customers. Although this is correlated with e-selling (15% of e-selling adopters also share catalog information online with customers), and may in fact be endogenous to the e-selling decision, including it as a separate control does not materially change the results (available upon request).

As discussed in §5, a bivariate probit analysis further helps address unobserved heterogeneity in plant taste for technology. This yields nearly identical results (available upon request).

8. Discussion

How can we leverage this pattern of facts to gain insight into how market leaders respond to innovative new business processes—and more generally, into innovation by firms? Without considering customer capabilities, reconciling all three sets of results would be difficult.

The e-buying results provide an initial "base case" that is useful for comparison. Leaders' robust willingness to adopt this frontier use of the Internet rules out the possibility that they resisted *any* new-to-the-world technology. Instead—and unsurprisingly—economies of scale appear to dominate. Consistent with Hypothesis 1, the business process innovation that demanded the least in the way of new capabilities was disproportionately pursued by the highest market-share firms.

Surprises arise, however, with the juxtaposition of the e-selling and ERP results. On its own, the e-selling result would appear consistent with an internal adjustment costs story (Hypothesis 2). Leader resistance to e-selling during these early stages of diffusion is robust across a range of specifications and subsamples of the data, and e-selling was inarguably a more complex process change than e-buying. However, by all accounts, the internal challenges of deploying ERP technology were even *worse* and tended to increase dramatically with the complexity and scale of a firm's operations (Gattiker and Goodhue 2004). And yet, although market leaders systematically resisted adopting e-selling, they overwhelmingly populated the ranks of ERP adopters in this representative sample. This presents a puzzle for any intuition rooted only in internal firm capabilities.

In fact, a more complicated econometric model that interacts market share with all of the other main covariates (available upon request) shows that higher-market-share firms suffer *less* from internal organizational complexity when it comes to e-selling adoption. For instance, the lower adoption propensity associated with vertically integrated commodity flows and a greater number of locations is significantly lower for the highest-market-share organizations. Internal adjustment costs might help explain the lower *average* adoption of both e-selling and ERP, but they fail to fully rationalize the market leader effect in these regressions.

Support for interpreting this as a customer-driven phenomenon comes from further unpacking the e-selling results. The uncommon size and representativeness of the Census Bureau data make it possible to segment the analysis by different industry settings. Doing this reveals the leader penalty to be mitigated or even reversed in lower-competition markets, B2C markets, and the apparel industry—contexts where customer-related adjustment costs were either relatively less important or unusually low. Visibility into plant-level variation in the capabilities of customers reinforces this new intuition at a granular level. When market leaders ship to locations with more IT-savvy customers, they are themselves more likely to adopt e-selling. Even more compelling, this effect is magnified in less-urban areas, where transferring process capabilities within the value chain might be relatively more important because of fewer external resources to support process innovation.[21] Overall, these results are consistent with customers' capabilities exerting an important influence on the innovative behavior of leading firms.

[21] Forman et al. (2008) found that firms outside of dense urban environments have to rely on resources elsewhere within the firm to support new IT adoption. An intriguing possibility hinted at by this result is that the causality runs from customers with frontier IT to process innovation among their supply base, with a transfer of knowledge running upstream within the value chain. Exploration of this hypothesis, however, is beyond the reach of these data.

9. Conclusion

The goal of this paper has been to deepen our understanding of how alignment between the demands of new technologies and the capabilities of firms influences the distribution of innovative activity within a market. A rich theoretical literature has returned to this question time and again, but it has typically ignored how capabilities external to the firm condition its response to technological change. By studying this question in a novel setting that invites careful consideration of firm-to-firm interactions, this paper makes progress on two fronts.

On the theory side, it contributes a new conceptual framework exploring how customers' capabilities might influence the innovative activity of market leaders. Rather than just presenting a novel perspective for consideration, it grounds the analysis in familiar territory by extending existing innovation concepts into the business process context. It focuses additional attention, however, on the role that process complexity and customer impact might play on leader behavior. This provides a springboard for testing existing intuitions in a new setting and motivates an approach for disentangling internal frictions from external ones in new ways.

The empirical contribution comes from leveraging rich data on uses of new Internet technologies that (a) correspond well to the margins of firm behavior highlighted in the framework and (b) span a range of industry settings. The results, which would be inaccessible without the wealth of information on both internal firm characteristics and external market linkages, yield a puzzle for internally rooted explanations of firm behavior. Careful consideration of customer input to the innovative process suggests that, in the business process setting, market leaders are most willing to innovate when their customers are, too.

The finding that customers' adjustment costs may dominate for important types of innovative activity has important strategic implications. Even well-positioned firms with strongly aligned capabilities may fail to innovate if doing so requires significant investments from their business partners. Predicting how technological advances will be distributed within a market, therefore, requires a detailed understanding not only of participants in the market itself but also of the interdependencies with external value chain partners—and the capabilities *they* possess.

This study has broader research implications that are worth noting. One is the importance of understanding the features of an innovation at a very detailed level and exploring heterogeneity within a given class of technologies. Although this understanding is not new to the innovation literature (e.g., Gatignon et al. 2002), it is driven home by the starkly different findings for e-buying versus e-selling—despite the common convention of lumping them together within the single term "e-commerce."[22] Distinguishing among target markets for an innovation—in this case B2B versus B2C—also emerges as an essential distinction. Yet this type of data is rarely available in large samples and has become less so.[23]

However, abandoning large-sample studies in pursuit of more institutional detail entails pitfalls that are also apparent in these results. A single-industry study of e-selling that might happen to take place in the relatively tractable apparel industry (800 plants versus the 5,300 in fabricated metal products) would, at the very least, miss theoretically important insights arising from the cross-industry comparisons. Arguably, the conclusions (i.e., that market leaders would seem to lead in e-selling adoption) would also quite simply be wrong outside of this context. Thus, these results argue for the benefits of studying firms' innovative activities in multiple-industry contexts whenever possible.

To what extent are these results generalizable? The innovations studied here, although widespread and growing with the diffusion of new information technology, differ in important ways from the patented product innovations that motivate most innovation studies. In particular, the difficulty of forestalling competitors via intellectual property protection appears to be an important distinction. This may help explain the finding that market leaders innovate *less* in the face of increased competition, counter to important product-based arguments that they will tend to innovate more (e.g., Gilbert and Newbery 1982, Aghion et al. 2005). Therefore, these findings might apply best to product innovation in contexts where intellectual property protection is weak or other practices (such as secrecy) are more widely used. At a minimum, they add to a growing body of work suggesting that nonpatent data can provide useful insights regarding the innovative activity of firms more generally (e.g., Roach and Cohen 2013).

Moreover, these findings are subject to several important limitations. Leveraging data collected by the U.S. Census Bureau overcomes many empirical challenges, such as how to accurately characterize overall market

[22] The unique exception I know of is Hollenstein and Woerter (2008), who separately explored e-buying and e-selling adoption in a sample of Swiss firms in 2002 (although their finding that e-buying and e-selling share the same drivers of adoption stands in sharp contrast to what I find in the United States three years earlier).

[23] Current official statistics on e-commerce in the United States report all e-commerce sales by manufacturers or merchant wholesalers as B2B (U.S. Bureau of the Census 2011). Yet, as early as 1988, firms in manufacturing varied in their B2B versus B2C focus: at least 11% of establishments surveyed in the Survey of Manufacturing Technologies reported "consumers" as their primary market (U.S. Bureau of the Census 1989). After 1999, the distinction between buying and selling was eliminated from the official e-commerce statistics (U.S. Bureau of the Census 2002).

and firm characteristics when the core data are collected for only a subset of establishments. However, many important variables—including the dependent ones—are available only for a single year. This prevents exploration into the precise timing of investment decisions. In addition, the survey only reports on firm behavior during an early stage of commercial Internet diffusion, leaving open the question of how these effects might evolve as technologies become more mature and/or adoption becomes more widespread. Last, the single cross section of data makes it challenging to control for firm characteristics whose omission might bias the empirical results. Although the results are based on robust conditional correlations including a very rich set of control variables, strict causality is beyond the reach of this data set.

Finally, innovative activity focused on improving business processes warrants further attention by both theorists and empirical scholars. This paper takes a step toward meeting this need, shedding light on important strategic considerations for both adopters of new business process technologies and their customers. In particular, the *inter*-firm coordination challenge looms large in this setting—and more generally, as businesses grow ever more dependent on the performance of their extended value chain. If larger firms lag in developing these "co-invention capabilities," smaller firms may enjoy new opportunities to leapfrog their competitors through business-to-business process innovation.

The findings presented here can only hint at what the long-term competitive implications might be. Yet they offer a springboard for future research that may deepen our understanding of the role that alignment between different types of innovation and different firm capabilities—both internal and external—plays in competitive strategy and market outcomes during periods of technological change.

Acknowledgments

Many thanks are due to Shane Greenstein, Scott Stern, Rebecca Henderson, Juan Alcacer, Chris Forman, Andrew King, Steven Kahl, Alfonso Gambardella, J. P. Eggers, and three anonymous referees. The author is indebted to T. Lynn Riggs, Jim Davis, and other members of the Center for Economic Studies for their support. The research in this paper was conducted while the author was a Special Sworn Status researcher of the U.S. Census Bureau at the Chicago and Boston research data centers. Research results and conclusions expressed are those of the author and do not necessarily reflect the views of the Census Bureau. This paper has been screened to ensure that no confidential data are revealed. Support for this research at the Chicago Research Data Center from the National Science Foundation [Awards SES-0004335 and ITR-0427889] is also gratefully acknowledged. In addition, the author is thankful for financial support from the Census Bureau's Dissertation Fellowship program and the State Farm Companies Foundation Dissertation Award. All errors remain those of the author.

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