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

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Working Paper

10-104

January 25, 2013

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October 2012

Abstract:

This paper explores the relationship between market position and business process innovation. Prior research has focused on the alignment between new technologies and the *internal* capabilities of firms to pursue them. I extend the investigation to include *external* capabilities as well. I develop a framework for predicting whether market leaders will undertake business process innovation based on the complexity of the process, the firm's organizational structure, and the innovation's impact on customers. I test its predictions in the context of e-business adoption using a large multi-industry data set. Robust conditional correlations suggest that market leaders were more likely to adopt new e-business practices only in settings that required little customer investment or where customer capabilities were well-aligned with the new technology. Otherwise, leaders' adoption was significantly lower than that of their less-prominent competitors. The findings highlight the strategic significance of adjustment costs in technology adoption, both within and beyond the firm boundary.

* **Harvard Business School, 431 Morgan Hall, Boston, MA 02153.** Many thanks are due to Shane Greenstein, Scott Stern, Rebecca Henderson, Juan Alcacer, Chris Forman, Andrew King, Steven Kahl, Alfonso Gambardella, participants of the Colloquium on Competition and Competitiveness, and numerous others I met while on the job market. I am indebted to T. Lynn Riggs and other members of the Center for Economic Studies for their support. The research in this paper was conducted while I was a Special Sworn Status researcher of the U.S. Census Bureau at the Chicago and Boston Census Research Data Centers. Research results and conclusions expressed are my own 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 RDC from NSF (awards no. SES-0004335 and ITR-0427889) is also gratefully acknowledged. In addition, I am thankful for financial support from the Census Bureau's Dissertation Fellowship program and the State Farm Companies Foundation Dissertation Award. All errors remain my own.

1. Introduction

Since the pioneering work of Joseph Schumpeter (1934, 1942), scholars have explored why certain innovations are adopted quickly by market leaders while others are ignored or absorbed only slowly. Prior work suggests that market leaders may have the greatest incentives to innovate in many instances (Gilbert and Newbery 1982; Athey and Schmutzler 1992); however, they may vary in their ability to do so (Henderson 1993, Arora et al. 2009). A principal tradition in the literature highlights the need for alignment between the nature of the technological change and the capabilities of incumbent firms (Abernathy and Clark 1985, Tushman and Anderson 1986, Henderson 1993, *inter alia*). Capability misalignment is blamed for the observed failure of healthy firms to maintain their technological – and often competitive – advantage over time. This, in turn, has implications for market structure and firm strategy in the face of technological change.

The rich literature on how capabilities may condition incumbents' reaction to technological change has focused primarily on *internal* characteristics of firms and their technologies.[1] A notable exception is Abernathy and Clark (1985), which surfaces the risks for incumbents when innovation makes new demands of existing customers. Afuah and Bahram (1995) emphasize the importance of technology-capability alignment throughout the entire value chain. I build on prior work by investigating, both theoretically and empirically, how market leaders react when an innovation demands inputs not only from within the firm but from its customers, as well.

I first develop a framework for predicting whether and when market leaders will participate in *business process* innovation – a type of innovative activity that has received little attention in the literature but has become quite important in recent years (Brynjolfsson and Saunders 2010). I then test these predictions in a large multi-industry data set on e-business adoption. I find that, while internal adjustment costs may explain adoption patterns on average, the behavior of leading firms varies most according to an innovation's impact on customers.

Business process innovations provide a useful context for studying the influence of customers on innovative activity because their development and use are often not confined by traditional firm boundaries. However, the context poses a challenge for leveraging the standard frameworks: prior research has focused primarily on product innovation (Cohen and Levin 1989, Gilbert 2006), with limited attention to physical manufacturing processes (Klepper 1996, Cohen and Klepper 1996, Dewar and Dutton 1986, Sull et al. 1997). Yet theory and evidence suggest that process innovation may differ in important ways from the product-focused variety (Utterback and Abernathy 1975, Adner and Levinthal 2001, Pisano 1997, Henderson et al. 1998), and that the drivers of innovation in business or

[1] For reviews of this literature, see Gatignon et al. (2002) and Chesbrough (2001). Christensen (1997) usefully highlights the impact that customers have on the rate and direction of incumbent innovation, but the mechanism remains largely focused on internal capability development within firms (Henderson 2006).

administrative processes further differ from those for physical process (Kimberly and Evanisko 1981). The scope for generalizing outside of these familiar contexts is therefore unclear.

To extend the literature into the business process context, I begin with the premise that economies of scale will promote adoption by market leaders. However, adjustment costs particular to business process innovation may also scale with firm size and market share. I focus in particular on the costly and uncertain activity of bringing business processes, organizational structures, and technology into alignment – both within and between firms. I argue that these adjustment costs are likely to be greater in the presence of: 1) complexity in the underlying process, 2) complexity in the surrounding organizational structure, and 3) high impact on customers. Moreover, these costs are likely to be greater for higher market-share firms. My core prediction is that market leaders, despite their size advantage, will ultimately be less likely to adopt in the presence of significant costs along these three dimensions.

I test this prediction and its underlying mechanisms using U.S. Census Data on over 34,000 plants across 86 different manufacturing industries. I focus first on e-selling, which in the early years of its diffusion had high adjustment costs according to the framework. Controlling for a wide range of organization and market characteristics, the results show that market leaders were indeed less likely to adopt e-selling than their less-prominent rivals. However, this pattern is not well-explained by internal adjustment costs, but rather by external factors. A comparison across other e-business practices and different industry contexts reveals that market leaders were in fact *more* likely to adopt in settings where the need for input from customers was low or where customer capabilities were well-aligned with the new technology. Ultimately, capability misalignment is associated in this context with less innovation by the largest, most successful firms; in contrast to prior work, however, the locus of the key misalignment appears to lie outside the firm boundary.

A rich body of existing theory offers many internally-focused reasons for why market leaders may falter in the face of new technology. Firms tend to develop routines (Nelson and Winter 1982) and information filters (Arrow 1974) based on prior experience that condition how they react to changes in their environments. As firms grow and age, routines become difficult to change because they become reflected in the technologies and organizational structures within the firm (Orlikowski 1992). Larger, more-established firms will 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 investments that propelled a firm to succeed in the first place 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 technology to be too costly.

Despite this rich theoretical tradition, empirical tests have proven challenging. The extensive body of empirical work addressing the response of high market-share firms to new technological opportunities has been described as "notable for its inconclusiveness" (Cohen and Levin 1989). While more recent studies have made econometric advances (e.g., Blundell et al. 1999), the empirical literature has been criticized for failing to account for underlying industry heterogeneity (Cohen and Levin 1989), for confounding product and process innovation (Gilbert 2006), and for abstracting away from relevant organizational capabilities (Cohen 2010). Progress has been made in single-industry settings including 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). A secondary contribution of this paper is robust evidence that accounts for variation in capabilities while spanning a range of industry and firm settings.

To the extent that business process innovation is difficult to observe, much less imitate, it may confer sustainable competitive advantages on adopters. In this respect, this paper also contributes to a large economics and strategy literature on the competitive implications of technology adoption (see Cohen 2010 for a review). The paper also contributes to the literature exploring customer participation in innovation (Morrison et al. 2000; Kahl 2007, Chatterji and Fabrizio 2012, Baldwin and von Hippel forthcoming) as well as a small information systems literature on the adoption of administrative innovations (see Swanson 1994).

2. Framework and Hypotheses

2.1 Benefits for Market Leaders: Market Power and Economies of Scale

Building on Schumpeter's original framing, a great deal of prior research has focused on 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 on innovation (Cohn and Levin 1989, Cohen 2010). Much of this prior work focuses on R&D expenditures in the context of exclusive rights (usually patents) to innovative outputs (Gilbert 2006). In the context of IT-based process innovation, however, patents have historically not been the primary means for appropriating returns from innovation (Mann and Sager 2007). In the case of *non-exclusive* rights, firms with greater market power are argued to be more likely to innovate because lower competition increases the returns to investment in 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 innovation is employing them in a firm's operations. As long as there are significant fixed costs involved, adopters with greater market share will be able to spread these costs across a higher volume of output. Typically applied to innovation in physical processes (e.g., Cohen and Klepper 1996), the logic extends naturally to business process setting (Kimberly and Evanisko 1981).

In cases where adoption costs do not also scale proportionally with firm output, the prediction is typically that larger producers will enjoy greater benefits from adopting – a prediction that is robust to a wide range of assumptions (Athey and Schmutzler 1992). However, some or all of the size advantages in business process innovation may, in fact, be overwhelmed by internal and external adjustment costs that are also higher for market leaders.

2.2 Costs for Market Leaders: Internal and External Adjustment Costs

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, in order to take advantage of frontier technologies, adopters often needed new capabilities. Existing processes often fell short of the "best practices" embedded in the latest software. Existing organizational features (e.g., departmental divisions, employee skills, etc.) did not always support the new ways of doing business. Waves of business process reengineering and often-disruptive organizational change followed (Hammer 1990). Incompatibilities with legacy IT systems added to adoption hurdles. Where process innovations spanned firm boundaries, they demanded complementary investments from actors outside the adopting firm, as well.

As a result, the path to technological and organizational alignment was often difficult to foresee and posed significant risks to existing operations – particularly during early stages of the internet's diffusion. Like more-traditional types of innovation, this "co-invention" (Bresnahan and Greenstein 1996) of new processes, supporting organizational structures, and IT entailed a wide range of adjustment costs. For certain types of business processes and firms, the alignment between the demands of the new technologies and existing capabilities was good – and, hence, the adjustment costs were minimal. For many others, however, the gap was large and costly to span – especially for leading firms.

For although market leaders might enjoy significant advantages in business process innovation, they face significant disadvantages, as well. Prior work has emphasized a range of organizational challenges for incumbents when technologies align poorly with their pre-existing competencies (e.g., Tushman and Anderson 1986, *inter alia*). The remainder of this section builds on this work by exploring factors that will tend to increase the costs of innovation specifically in the context of new business processes, and particularly for leading firms. The goal is to motivate not only the core hypothesis but also a series of secondary hypotheses for testing the underlying mechanisms. Before delving into these details, however, the baseline hypothesis is simply that:

HYPOTHESIS 1. *Market leaders will be less likely than other firms to adopt business process innovations with high levels of internal and external adjustment costs, all else equal.*

The validity of this test relies on correctly identifying which characteristics of innovations and firms will represent "high adjustment-cost" cases. It thus becomes essential to understand, in detail, how the costs of bringing new process logic, organizational structures, and information technology into alignment will vary by features of the process itself, as well as by features of the organizational context and aspects of the customer relationships in which the transformation would occur.

2.2.1 Process Complexity

Prior research suggests that IT adjustment costs tend to be systematically higher wherever there are complex processes involved (Bresnahan and Greenstein 1996). Because business processes consist of a number of related tasks whose execution needs to be coordinated for optimal performance (Davenport 1993), the complexity of a given business process can be driven both by the set of tasks that comprise it and by how they are related to each other. At the task level, the concept of complexity is generally associated with a greater number of distinct components and information cues (Wood, 1986) as well as greater uncertainty in the steps needed to complete the work (Van de Ven et al. 1976). At the process level, complexity is argued to increase in the interdependence among tasks (Simon 1982; Wood 1986; Nickerson and Zenger 2004). Changes to how one task is performed may require complementary innovation in related areas of the firm (Milgrom and Roberts 1990, Orlikowski 1992). This increases the amount of knowledge and coordination required to implement process change. The product innovation literature has noted the challenges faced by incumbents when interdependencies between *product* components are affected by new technologies (Henderson and Clark 1990). The analog in the business process setting is the set of *tasks* that are operationally interdependent within the firm.

Complexity in business processes increases the knowledge required to understand them (Wood, 1986), as well as the managerial investment required to transform how they are structured and executed within the firm. All else equal, process complexity will tend to be greater for market leaders. High market-share incumbents are likely to have grown through experience, developing routines (Nelson and Winter 1982) and formal coordinating processes (Van de Ven et al. 1976) for addressing a wider range of challenges over time. Larger, more-established firms also tend to be more diversified (Villalonga 2004), requiring a greater diversity of routines. To the extent that they have been successful as a result of good alignment and coordination amongst their various activities, the formal linkages amongst these tasks are also likely to be greater for market leaders. Thus, changing the business processes at leading firms is likely to require greater investment in communication and coordination across the firm (Edmondson et al. 2001; Sharma and Yetton 2003) – i.e., higher adjustment costs. Therefore:

HYPOTHESIS 2. *Process complexity will disproportionately reduce the likelihood that market leaders will adopt business process innovations, all else equal.*

2.2.2 Organizational Complexity

Another driver of business process complexity exists not at the level of the process itself, but at the level of the organization in which it is embedded. An otherwise-straightforward activity executed across multiple specialized subunits within the firm will be more complex than the same activity executed for a single-unit firm because the number of distinct tasks will be greater (Wood 1986), as will the coordination required amongst them (Becker and Murphy 1992). Organizational complexity has been defined and measured in a variety of ways (Damanpour 1996); measures related to increased coordination at the level of the firm include the number and diversity of units (Blau and McKinley 1979; Kimberly and Evanisko 1981) and their degree of spatial differentiation (Blau 1970). Analogous to the process-level construct, operational interdependency across firm subunits has been argued to demand greater investments in coordination and integration throughout the firm (Barki and Pinsonneault 2005).

For a variety of reasons including firm age and survival (Dunne et al. 1988), as well as diversification into new product markets and geographies (Audia et al. 2001), larger incumbents will tend to exhibit greater diversity and geographic dispersion of organizational subunits. To the extent that they may be more vertically integrated, larger firms may also have greater interdependencies amongst organizational subunits, as well (Sorenson 2003). Thus, organizational complexity along these dimensions is expected to increase adjustment costs disproportionately for market leaders compared to other firms. It may also simultaneously diminish top-line benefits of adoption if heterogeneity amongst different subunits within the firm decreases economies of scale in a given business process innovation. Thus, another mechanism that could contribute to Hypothesis 1 is:

HYPOTHESIS 3. *Organizational complexity will disproportionately reduce the likelihood that market leaders will adopt business process innovations, all else equal.*

2.2.3 Impact on Customers

Managing change to a firm's core activities and routines is sufficiently challenging when the primary stakeholders function within the boundaries of the same firm. However, a successful customer-related business process innovation will typically require significant external coordination to ensure that the desired information and process flows also meet customer needs. Yet, the costs of coordinating across firm boundaries will typically be higher for a variety of reasons, including the lack of a "common language" (Arrow 1974), the absence of formal hierarchy (Grant 1996), and a range of transaction costs in exchanging knowledge flows across firm boundaries (Grant 1996, Nickerson and Zenger 2004). These costs are argued to be higher for more complex (Nickerson and Zenger 2004) and ongoing interactions (Gulati and Singh 1998). Moreover, not only must these higher costs be borne by the adopting firm, but the adopting firm must ask its customer(s) to bear them, as well. Because these complementary adjustment costs may increase the effective price of purchasing from the adopting firm, this could be competitively risky. The magnitude of this combined "impact" of customer-related coordination costs and competitive risks will depend on how well-aligned existing customer processes and organizational structures are with the new technology and business logic.

For a given distribution of customer capabilities in a market, the impact of external adjustment costs will arguably be greatest for market leaders. High market-share firms will have more and potentially more diverse customers, increasing the complexity and hence the difficulty of optimizing the firm's response to all customer needs. The chance of being misaligned with a particular need or expectation will be greater for firms with more customers, as will the time required to assimilate and address the entire range of customer requirements. To the extent that market leaders may be in long-standing trading relationships with other large, established firms, inertia associated with incumbency and a desire to protect a strategically important relationship may exist on *both* sides of the interaction. Thus:

HYPOTHESIS 4. *A high impact on customers will disproportionately reduce the likelihood that market leaders will adopt business process innovations, all else equal.*

3. Phenomenon: E-Business Adoption

The explosion of new business processes enabled by the diffusion of the commercial internet in the late 1990s offers a rich empirical setting for testing these propositions. Moreover, the context itself is of independent interest given the level and rate of firm investment in IT-related business process transformation over the past 20 years. Roughly one-half of all annual equipment investment by U.S. businesses is in information processing equipment and software, which grew from $183 billion in 1991 to over $548 billion in 2011 (U.S. Bureau of Economic Analysis 2012). Yet despite these numbers and the striking valuations of internet-focused technology providers at the time, the rates of e-business adoption by firms during the early years were considerably lower than is widely recognized.[2]

3.1 E-Selling

For ease of mapping the empirical applications to the theoretical framework, I focus primarily on the use of new internet-based technologies to conduct sales online (e-selling). It is important to note that, while the focus of this paper 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 impact of EDI in the empirical analysis (see Section 6).

[2] In a sample of 800 organizations across 10 verticals, AMR Research reported that "Almost 90% had a Website, but only 15% said customers could check an order's status over the Web, and only 6% allowed customers to order products over the Web," (AMR 1999b).

Early e-selling was associated with high levels of adjustment costs according to the framework above. To begin, there was no "one-size-fits-all" technology to support the new sales process. Existing software solutions focused primarily on finished goods (e.g., computers, clothing, consumer packaged goods, etc.) for sale to distribution partners and customers. This included both commercial entities ("business-to-business" or "B2B" sales) and end-consumers ("business-to-consumer" or "B2C" sales). 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," (AMR Research 1999b).

Due to the diversity and strategic importance of this customer-related business process, the majority of adopters chose a hybrid approach involving both a high level of customization of available software and some business process reengineering (AMR 1999b) – i.e., a high level of "co-invention." A recurring theme among industry observers and analysts at the time was the significant time and money required to undertake the coordination and customization involved.[3] Process complexity was explicitly cited as a barrier to wider diffusion of "sell-side" e-commerce solutions (AMR 1999b).

Another salient characteristic of e-selling was that the affected processes typically involved multiple locations and functions throughout the firm. The pressure to create and maintain a unified online presence required that entire product families (often produced at separate plants) and related services be supported by one comprehensive website. E-selling also interacted with other strategically sensitive business functions focused on brand image and customer relationship management. For many firms, this generated interdependencies among internal firm units that may not have existed before.

E-selling, almost tautologically, also impacted customers. The magnitude of this impact was greatest in the case of B2B transactions, where negotiations and contracts are typically more complex and customer-specific than in B2C. To move to an internet-based sales process, a firm and its customers needed to collaborate on what the online sales process should look like, what types of data ought to be exchanged, and where control for certain activities should reside. This typically opened up existing contracts for renegotiation (Davenport 1993). Also, discriminating amongst customers was more difficult on the open internet platform, requiring standardization and harmonizing of a wide variety of pricing and bundling strategies across customers, which many firms considered to be competitively risky (Anderson et al. 2010). These risks were widely believed to be greater for leading firms (Davenport 1993).

[3] Even the notable successes, such as the launch of milpro.com by tool-manufacturer Milacron, Inc., 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).

3.2 E-Buying

It is useful to contrast e-selling with another inter-organizational business process innovation that diffused around the same time: e-buying. Early e-buying solutions were tailored to three distinct types of purchasing processes: indirect purchasing, direct purchasing, and finished goods purchasing.

The most widely-known e-buying applications were focused on enabling online procurement of maintenance, repair, and operations (MRO) goods such as lubricant, spare parts, office supplies, etc. – i.e., anything consumed in the production process not directly put into finished goods. This *indirect* procurement centered on spot transactions involving highly standardized inputs. For adopters of e-buying solutions, implementation typically involved restructuring the internal process flow for approving purchase orders, improving access to pre-approved vendors, and generating alerts for purchases that required managerial attention. While cost savings from electronic indirect procurement were significant – upwards of 70% per purchase order (AMR Research 1999a) – 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 – involved in indirect e-buying were much lower than those for the typical e-selling implementation (AMR 1999a).

This highly standardized indirect procurement process stands in sharp contrast to the other two types of procurement, which better mirror the more-complex sales processes. *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 solutions were available to effectively manage direct procurement processes online (AMR Research 1999b). Solutions for *finished goods* procurement by downstream firms were available; however, they were tailored to the needs of retailers – and not the manufacturing firms that are the focus of this study.

3.3 Internal Use of Computer Networks

Finally, an important facet of e-business diffusion in the late 1990s was the increase in firm investment in *internally-focused* applications of information technology. Amongst a vast array of technologies, Enterprise Resource Planning (ERP) software has received great attention due to its notorious implementation challenges (Cliffe 1999). For the purposes of this study, it is important to note that because its implementation demanded significant process standardization and coordination throughout the firm, complementary organizational change, and other IT-related capabilities such as IT project management and training (Umble et al. 2003), it represents a useful example of complex, but internal, co-invention.

4. Methods

4.1 Empirical Model

To test the hypotheses developed in Section 2, I use 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., benefits net of technology and adjustment costs) will adopt first and that non-adoption in the cross section signals lower net benefits from that technology's use.

The estimating equation implied by the theoretical framework in Section 2 is:

$$\begin{aligned}\Pr(BPI_{ij}=1) = \Phi(&\alpha + \beta_1 LEAD_i + \beta_2 PROC_{ij} + \beta_3 (LEAD_i \times PROC_{ij}) + \beta_4 ORG_k \\ &+\beta_5 (LEAD_i \times ORG_k) + \beta_6 CUST_{ij} + \beta_7 (LEAD_i \times CUST_{ij}) + X_i\gamma + I_i\delta + \varepsilon_i)\end{aligned} \qquad (1)$$

where BPI_{ij} indicates whether plant *i* has adopted a business process innovation affecting process *j*, $LEAD_i$ is a measure of *i*'s market position, $PROC_{ij}$ is a measure of the complexity of process *j* at plant *i*, ORG_k is a measure of organizational complexity at firm *k* to which plant *i* belongs, $CUST_{ij}$ is a measure of the impact on *i*'s customers due to an innovation in process *j*. X_i represents a vector of plant-specific controls, including measures related to IT capabilities. I_i is a vector of industry dummies; ε_i is a plant-specific error term that is assumed to follow a normal distribution.

Due to the challenges of estimating and interpreting interaction effects in probit models (Ai and Norton 2003), I focus on the average marginal effects (AME) of the variables. The AME of β_1 captures the correlation between market leadership and the likelihood of adoption. Hypothesis 1 predicts an AME of $\beta_1 < 0$. While the AME of β_2 captures the average relationship between adoption and process-related co-invention costs, Hypothesis 2 actually concerns the AME of β_3: the *interaction* between market share and process complexity. This is expected to be < 0. The AME of β_4 and β_5 measure the equivalent relationships for organizational complexity; Hypothesis 3 predicts an AME of $\beta_5 < 0$.

As the data do not contain plant- or firm-level variation in customer characteristics, there is no straightforward way to estimate β_6. I address this in part by including industry fixed effects to control for customer characteristics that will drive external adjustment costs and also vary systematically by industry. To test the prediction in Hypothesis 4, which focuses on the interaction between market leadership and customer impact (i.e., β_7, which is predicted to be < 0), I pursue two approaches. First, I exploit the sharp difference between e-selling and other business process innovations – such as e-buying – in their impact on customers, estimating the leadership effect in a bivariate probit model that separates yet simultaneously addresses both types of business process innovations:

$$\Pr(BPI_{iB} = 1) = \Phi(\alpha_B + \beta_7^B LEAD_i + X_i\gamma + I_i\delta + \varepsilon_{iB}) \text{ and}$$
$$\Pr(BPI_{iS} = 1) = \Phi(\alpha_S + \beta_7^S LEAD_i + X_i\gamma + I_i\delta + \varepsilon_{iS}) \qquad (2)$$

where $j = B$ indicates e-buying and $j = S$ indicates e-selling. Under the assumption that e-selling represents an innovation with high demand for customer capabilities and e-buying represents an innovation with none, the expectation is that $\beta_7^S < 0$, and, by extension, that $\beta_7^B > \beta_7^S$. If internal adjustment costs are insignificant for e-buying, the advantages of economies of scale should dominate, and $\beta_7^B > 0$ due to the lack of external adjustment costs. To further explore this logic and better isolate the external (customer) effect from internal adjustment costs, I also compare e-selling to ERP adoption.

My second approach to disentangling the effect of customer impact on business process innovation is to exploit industry-level variation in the demand for customer input in the innovative process. Details are provided in Sections 5 and 6.

4.2 Identification

My research design relies on three strategies to identify the effects of market position on business process innovation. The first is to use a rich set of controls for observed and unobserved factors that might bias 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). Unobserved effects arising from specific industry contexts, potentially including product market competition, are addressed by including a rich set of industry dummies at a relatively granular (4-digit NAICS) level.

Statistically, identification in this model would require that market share and other explanatory variables not be simultaneously determined with adoption. While it is virtually impossible to control for all potential sources of endogeneity with this data, this common concern (Gilbert 2006) is in some part mitigated by using values for all non-IT explanatory variables that are lagged by two years.

My third approach 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, 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 control for potentially confounding influences such as unobserved firm-specific “taste” for technology adoption. A firm that is disproportionately likely to adopt *any* kind of new

IT will bias the bivariate probit results towards adoption of *both* business process innovations. Technology laggards will have an equivalent negative tendency to adopt both technologies. Thus, the *difference in leadership effects between the two technologies* identifies how market leaders respond to high- versus low-co-invention business process innovations. To address the possibility that decisions for plants within the same firm may be correlated, all standard errors are clustered at the firm level.

5. DATA

5.1 E-Business Adoption

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

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 online sales primarily over the internet are coded as having adopted e-selling, similarly for e-buying.[4]

Based on this snapshot, the diffusion of e-business is broad: e-selling and e-buying takes place in every manufacturing subsector and along the entire size distribution. Yet it is not deep: only 30% of plants are estimated to have adopted internet-based e-commerce of some form (see Table 1). The adoption of e-buying is roughly 21% and e-selling is even lower at 15%.

These high-level summary statistics mask a great deal of industry heterogeneity in the use of internet technology. For instance, Computers & Electronics and the Printing industry have the highest penetration. In the former, roughly 21% of plants accept orders over the internet while 38% of plants place internet orders; in the latter, the percentages are 34% and 32% for selling and buying, respectively. Apparel is a trailing industry with around 7% for both e-selling and e-buying. Some industries lean considerably more towards one e-business practice than the other. Only 6% of Textile Products plants place internet orders, but over 16% accept them (see online appendix).

[4] A useful feature of this definition is that it excludes establishments that are merely experimenting with internet-based processes while still relying primarily on a different network (such as an intranet, extranet, or EDI) for its online transactions. This will reduce the likelihood of confounding borderline adoption or exploratory pilot projects with true business process innovation requiring substantial investment and co-invention by adopters.

Another important difference between e-selling and e-buying in the sample concerns the fact that the activities captured by the survey do not represent mirror images of a fixed 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, etc.). Thus, the supplier-side of the e-buying transaction is not included in the 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 econometric model).

5.2 Market Leadership

The primary explanatory variable is market share of the adopting plant. I leverage the 1997 Census of Manufactures (CMF)[5] to measure the total value of shipments in each industry[6] 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. To check robustness of these results, I also calculate market share of the parent firm, defined as the percentage of country-wide value shipped from all plants belonging to the same firm to which the plant of interest belongs; I also explore the effect of logged plant sales, logged plant profits, and size measured by the number of employees (see online appendix for details).

5.3 Process and Organizational Complexity

I use two measures to proxy for the complexity of the underlying business processes impacted by e-selling. The first captures whether or not the plant shares product descriptions or a catalogs with its customers online. The logic is that firms or firm units with the capability to share this type of information with their customers have invested heavily in standardizing their product descriptions and potentially their pricing, which might dramatically reduce the complexity of the underlying sales process. In these instances, the shift to online sales might be a relatively low-cost innovation.

The second measure specifically addresses the extent of process interdependence by indicating whether the firm to which the plant belongs transfers goods and services between plants within the firm. This measure has been used in prior work to proxy for the demand for within-firm coordination generated by greater operational interdependence (McElheran, forthcoming). Note that variation in this variable arises at the organization level, making it impossible to disentangle strictly process-based interdependence from organization-level linkages.

[5] Conducted every five years by the US Census Bureau, this census captures the value of all shipments from nearly all manufacturing plants in the country; response is required by federal statute.

[6] I define the relevant market by the 4-digit NAICS code reported as the primary product for each plant of interest. All core results are robust to using a 6-digit NAICS industry definition.

Other measures of organizational complexity rely on the 1997 CMF to observe all of the manufacturing plants belonging to the parent firm, even if they are not in the CNUS sample. These measures include the number of plants, the diversity of those plants in terms of the number of distinct primary product (NAICS4) classifications, and their geographic dispersion. The latter is a count of the number of metropolitan areas (MSAs) or counties (for rural plants) in which the parent firm operates.

5.4 IT Capabilities

A crucial insight from prior research is that leaders may, in fact, possess important capabilities that are well-aligned with a particular technological advance (e.g., Tushman and Anderson 1986). In the case of IT-based business process innovations, a crucial 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 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). While these capabilities are likely to reduce co-invention costs 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 providing a short-run substitute that imposes "switching costs" on prior-generation IT leaders (Klemperer 1995, Forman 2005). Because they tend to be both older and to have enjoyed economies of scale in the past, large incumbents are more likely to have invested in incompatible legacy systems.

The implications of these arguments 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, in general, is ambiguous and depends critically on the type of IT in use at the firm.

For these reasons, I explore a range of measures of IT-related capabilities derived from the CNUS survey. As 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 potentially less co-determined with the externally focused e-selling innovation. This measure of intensive use of internal IT is equal to 1 if the plant reports using networked computers in 2 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 (see Table 1). Other measures include the presence of fully integrated ERP software (15% adoption rate), local area networks or LAN (47% adoption rate), and legacy EDI technology (14% adoption rate).

5.5 Impact on Customers

Lacking data on plant-specific linkages outside of the firm boundary, my approach to testing Hypothesis 4 relies on two different sources of variation in the demand for customer input. The first is variation between the business 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 Section 3). I also compare e-selling to ERP adoption, to keep the internal adjustment costs comparably high across process types while again exploiting a sharp contrast in external coordination costs.

The second approach leverages industry variation in whether the e-selling transaction is likely to be primarily business-to-business (B2B) or business-to-consumer (B2C). B2B transactions arguably demand greater complementary co-invention by virtue of the fact that they often replace complex verbal and written negotiations over prices, bundles of products, and complementary services – typically in the context of repeated interactions between trading partners. In contrast, B2C transactions are typically straightforward arms-length interactions requiring little relationship-specific investment (at least on the part of the customer). The latter type of customer linkage is defined in the data by relying on the input-output tables published by the U.S. Bureau of Economic Analysis (BEA) to identify industries where 75% or more of the value in that industry is transferred to "Final Use" by consumers. It is important to keep in mind that B2C transactions will be the minority of transactions in this manufacturing-based data set: most B2C takes place between retail firms and final consumers not included in this survey.

6. Results

6.1 Probit Estimates of E-Selling Adoption

Table 2 reports the average marginal effects from a probit estimation of e-selling adoption. Column 1 reports the basic correlation with market share, including a parsimonious set of controls for age, employee skill mix, and the plant's primary industry classification. It reveals a significant negative conditional correlation between leadership and the likelihood of adopting: all else equal, a one-standard-deviation increase in the log of the plant's market share[7] would be associated with a 2.8 percentage-point – or 19% – decrease in the baseline adoption rate of 14.6%. This relationship is relatively stable across specifications and consistent with Hypothesis 1.

The next two hypotheses concern how process and organizational complexity influence the adoption behavior of market leaders. Econometrically, this requires interacting the market share variable with proxies for these characteristics. Before focusing on the interactions, however, it is informative to consider their direct effects. Column 2 introduces a measure of firm investment in reducing process complexity: whether or not the plant shares catalogs online with its customers. The 10-percentage-point

[7] Recall that market share and all other non-IT explanatory variables are lagged 2 years to 1997.

increase in the likelihood of e-selling adoption associated with the presence of an online catalog is both statistically and economically significant. In Column 3, the presence of operational interdependencies in the form of within-firm transfers is associated across specifications with a significant and sizable reduction of 5.4 - 7.8 percentage points in the likelihood of e-selling adoption. The next three columns add measures of organizational complexity. In Column 4, a one-standard-deviation increase in the number of plants at the parent firm is equivalent to a 1.3 percentage-point reduction in the likelihood of e-selling. A comparable effect is found for plant diversity (Column 5) and geographic dispersion (Column 6). While these results do not speak directly to the main hypotheses, they are consistent with the theory development in Section 2, suggesting that internal adjustment costs serve to reduce the *average* rate of business process innovation.

The next two columns explore various IT-related capabilities. Intensive internal use of computer networks is associated in Column 7 with a 6-percentage-point greater likelihood of e-selling. A similar effect is found for the presence of LAN technology in Column 8 and the presence of ERP (see online appendix), suggesting that firms with significant prior investments in internal IT systems may have capabilities that are complementary to e-selling adoption. In contrast, legacy EDI systems appear to substitute for e-selling, decreasing the adoption likelihood by roughly 8 percentage points. Thus, as expected, different types of IT have different associations with the average likelihood of e-selling adoption; however, including these controls has a negligible impact on the other effects.

Columns 9a and 9b of Table 2 address the central question of how market leaders react to higher adjustment costs, in particular those related to process and organizational complexity. To obtain these results, I construct an indicator variable for whether the plant's market share is above the 75th percentile for its industry (NAICS4), [8] interact it with the key explanatory variables in the preceding specifications, and report the marginal effects averaged over each value of this indicator. Despite their significant direct correlation with the likelihood of adoption, the interaction effects are *not consistent* with Hypotheses 2 and 3. If anything, they suggest that market leaders have superior capabilities for addressing process and organizational complexity: the correlation between online catalogs and e-selling adoption for larger incumbents is half the magnitude reported for smaller plants, as is the correlation with within-firm transfers. These differences are statistically significant: the 95% confidence interval for the catalog variable is [.084, .146] for the lower-share plants and only [.031, .067] for the higher-share plants. The range on within-firm transfers is [-.079, -.040] for lower-share plants versus [-.037, -.009] for the leading ones. The influence of number of plants is significantly negative at the smaller end of the market share

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[8] The results are robust to cutoffs for "high market share" between the 50th and 85th percentiles. Lower thresholds introduce significant noise in the estimates; higher thresholds dramatically reduce the number of observations – and hence the power – of the empirical test.

distribution (in the interval of [-.012, -.004] with 95% confidence), yet it is not statistically different from zero, ranging within [-.003, .001] for the leading establishments.

6.2 Cross-Process and Cross-Industry Comparisons

The inconsistency of the results with the predictions of Hypotheses 2 and 3 raises the question of whether customer impact (Hypothesis 4) may be the primary mechanism underlying the robust negative correlation between market share and business process innovation observed in Table 2. Table 3 addresses this question first by comparing adoption rates across different types of business process innovations and then comparing e-selling adoption across different industries.

6.2.1 Bivariate Probit Estimates

Columns 1a and 1b of Table 3 report the average marginal effects from a bivariate probit estimation of equation (2), where e-buying and e-selling are treated as separate but correlated adoption decisions. The most striking finding is that, while market leaders are disproportionately less likely to adopt e-selling, they are nearly equally *more* likely to adopt e-buying. According to the results, a one-standard-deviation increase in logged market share would be equivalent at the highest significance levels to a 4.7 percentage-point increase in the likelihood of e-buying adoption – an increase of 22% over the baseline e-buying adoption rate of 21.3%. To the extent that the margin between e-buying and e-selling captures stark differences in the demand for customer investments in the business process innovation, this could be taken as evidence consistent with Hypothesis 4.

However, there are many differences between e-buying and e-selling besides their impact on customers. In addition to the anecdotal evidence on differences in their overall process complexity (see Section 3), the other effects reported in columns 1a and 1b point to additional dissimilarities. In particular, the effects for the process and organizational complexity variables are not statistically different from zero for e-buying, whereas they are quite large in the e-selling equation, suggesting that internal co-invention only matters on average for the inherently more-complex and idiosyncratic e-selling process innovation.

Column 2a and 2b compare e-selling to ERP adoption. The idea is that the latter innovation will be similarly affected by high levels of internal process and organizational complexity at the adopting firm, but only e-selling will demand inputs from customers. The bivariate probit estimates suggest that the benefits of scale do, indeed, dominate in the absence of customer impact: a one-standard deviation increase in logged market share would be equivalent to 3.4 percentage-point *increase* in the likelihood of adoption (a 39% increase over the baseline adoption rate of 15.2%). The effects of market share for e-selling remain largely unchanged. A similar result holds when the internal intensive use of IT in the production process (as described above) is used instead of ERP (not shown). These comparisons across process types again suggest that the arguments behind Hypotheses 2 and 3, which focus on process and organizational complexity, are not the root cause of the systematically lower adoption of e-selling by leading firms.

6.2.2 Probit Estimates with Interactions

The ideal way to test whether customer impact is driving the observed adoption patterns would involve a plant- or firm-level measure of customer capabilities and how existing interactions might be impacted by the move to e-selling. Lacking data on an individual organization's customers, however, I take advantage of industry-level variation in customer impact to explore this relationship. Based on the argument that B2C transactions demand significantly less complementary co-invention on the part of customers than B2B transactions, and the assumption that industries where a greater proportion of output goes to final use by end consumers will tend to have more B2C transactions, Columns 3a and 3b report the results of a probit estimation of e-selling adoption where all covariates are interacted with an indicator of whether the plant is in an industry where e-selling is more likely to be B2C.[9] Strikingly, the sign and magnitude of the average marginal effect for logged market share are completely reversed in the B2C segments: a one-standard-deviation increase in logged market share would be equivalent to a 2.3 percentage-point (or 30%) *increase* in the likelihood of e-selling adoption. The magnitude of the effect is robust to including the catalog indicator, however the statistical significance falls below conventional levels (see online appendix). To the extent that the B2B vs. B2C distinction captures variation in the demand for external co-invention, these results provide support for Hypothesis 4.

Column 4 of Table 4 provides a case-study reinforcing this interpretation. In nearly all regressions based on individual NAICS3 industry segments (see online appendix), the conditional correlation between logged market share and e-selling adoption is negative (though not always statistically significant). The Apparel industry (NAICS code 315) stands out, however, in that the average marginal effect is *positive* and both economically and statistically significant: a one-standard-deviation increase in the logged market share variable for this industry would be equivalent to an increase in the likelihood of adoption of 4 percentage points over the baseline industry adoption rate of 6.7%.

Qualitative studies of the apparel industry in the late 1990s emphasize two distinctive features. The first is that apparel firms *and their customers* already shared well-developed standards for characterizing color and fabric in their communications – a significant hurdle to transacting on apparel purchases electronically (Hammond and Kohler 2001). They were also accustomed to catalog-based transactions, which were thought to facilitate the transition to e-selling for firms on both sides of the exchange (Hammond and Kohler 2001, AMR 1999b). While this could be interpreted as lower internal

[9] B2C is defined here as 75% or more of value in that industry going to "Final Use" according to the Bureau of Economic Analysis. The results are robust to increasing the threshold up to 90%; however, lowering the threshold generates a great deal of noise in the estimates.

process adjustment on the part of the selling firms, the effect appears even while explicitly controlling for the presence of online catalogs. Moreover, the qualitative evidence specifically emphasizes the advanced capabilities of customers of this industry compared to others during early stages of e-business diffusion. A detailed assessment of the readiness of customers in every industry segment is beyond the scope of this paper; however, the coincidence of a distinctive technology-capability alignment and an unusual positive propensity of large incumbents to pursue internet-based sales stands out in this case and is consistent with the mechanisms underlying Hypothesis 4.

6.2.3 Alternative Explanations and Robustness Checks

An alternative explanation to Hypothesis 4 is that large market-share firms protected from competition will be less likely to innovate because their opportunity costs of disrupting production are higher in the form of greater foregone rents, often referred to as higher "replacement" costs (Arrow 1962), and that they can resist innovating due to protection from competition (Gilbert and Newbery 1982). Columns 5a and 5b of Table 3 explore the influence that product market competition may have had on the observed pattern of results. Instead of simply controlling for a plant's primary industry classification, this specification leverages an estimated Lerner Index (as in Aghion et al. 2005) to see if the behavior of market leaders is systematically different under different levels of product market competition.[10]

The Lerner index is price minus marginal cost over price. Because actual margins and product prices are unobserved even in the rich Census data, I approximate them with a measure of profits over sales. Specifically, I divide the difference between total sales and production costs (materials and wages) by total sales and subtract from one: $1-\frac{\text{(sales- cost of materials-wages)}}{\text{sales}}$. 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 4-digit SIC code.[11]

The final columns of Table 3 report the estimated average marginal effects of an interaction between the standard covariates and an indicator of whether the plant is in a "high competition" industry, where the cutoff for this classification is having a weighted average Lerner index greater than the mean of 0.7. The first row of the last two columns is, essentially, a two-way interaction between market share and competitive pressure in the e-selling adoption equation (1). The negative average marginal effect for logged market share in these more-competitive industries is estimated to be -.037. This is in contrast to the -.012 for market leaders in historically less-competitive industries (Column 5a). This difference is

[10] While concentration ratios or a Herfindahl index are more commonly used to measure competition, they have the disadvantage of being correlated *by definition* with market share.
[11] Census shifted from SIC to NAICS classification in 1997, so SIC is used for consistency. The findings are robust to alternative constructions of the Lerner index including using five-year or unweighted averages.

statistically significant: the 95% confidence interval for the market share effect in the less-competitive industries is [-.019, -.004], which is significantly above the range of [-.045, -.028] for Column 5b. Two aspects of this result are worth noting. The first is that this pattern of results is inconsistent with a "replacement effects" story – product market competition does not seem to be useful for promoting e-selling adoption amongst high market-share firms. The second is that the effect in less-competitive industries, while smaller in magnitude, is still negative: firms with potentially more market power are not able to systematically compel adoption by their customers. Overall, this could be taken as evidence that competition made it more difficult for market leaders to induce exiting customers to agree to a uniform e-selling approach, whereas smaller competitors could tailor their offerings and demand less adjustment from their customers.

Taken together, the findings reported in Tables 2 and 3 are robust to a variety of variable definitions and econometric specifications. For instance, they hold for alternative measures of market leadership including: market share of the parent firm, logged plants sales, and logged gross profits. Size and market leadership are highly correlated – the results look similar when the log of plant employment is used instead of market share. Despite this collinearity, however, the results also hold when a control for plant size in terms of employment is included in the main regression. They are also robust to running the analysis without the Census Bureau-provided weights. See the online appendix for these results.

7. Discussion

How can we leverage this pattern of facts to gain insight about innovation, more generally? The most striking result is that, despite the common intuition that internal inertia can explain lagging adoption amongst leading firms, it provides a poor explanation in this economically important setting. If anything, the data suggest that the most successful firms may have significant but difficult-to-observe capabilities in coordinating process change in the presence of process or organizational complexity. While a detailed pursuit of this conjecture is beyond the scope of this paper, it has significant implications for post-adoption performance. If large firms are slow to adopt, but are ultimately better implementers, then the competitive consequences of being a technology laggard may be significantly mitigated.

The finding that, ultimately, external adjustment costs may dominate internal ones for important business process innovations has important strategic implications. Even well-positioned firms with strong complementary capabilities may falter in innovative activities that require significant input 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 of the interdependencies with external contributors to the innovation process – and the capabilities *they* possess.

Another insight emerging from the empirical analysis is the importance of understanding the features of an innovation at a very detailed level and exploring heterogeneity within a given class of technologies. While this insight is not necessarily new to the innovation literature (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." [12] Distinguishing amongst target markets for an innovation – in this case B2B vs. B2C – also emerges as an empirically vital distinction. Yet, this type of data is rarely available in large samples, and has become less so.[13]

However, abandoning large-sample studies in pursuit of more 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 forging and stamping) would, at the very least, miss theoretically important insights arising from the cross-industry comparisons. Arguably, the conclusions (i.e., that market leaders tend to lead in e-selling adoption) would also quite simply be wrong outside of the particular context. Thus, these results argue in favor of studying innovation in a wide range of industry contexts and carefully addressing external validity in single-industry studies.

Finally, both the theoretical framework and empirical results offer a complementary window on innovation processes that are 1) widespread and important in the U.S. economy, but 2) do not involve patented product innovations. While the finding that market leaders might fail to lead in innovation that demands new capabilities is not novel in the product-based literature, it actually *is* surprising given the strong economies of scale that should (and do) arise in most instances of business process innovation. A patent-centric view of the world might take both the predictions and findings for granted, despite the need for different theoretical assumptions (Gilbert 2006) and recent evidence that conceptualizing and measuring innovative activity using patents may miss important details (Roach and Cohen, forthcoming).

8. 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 with different market positions influences the distribution of innovative activity within a market. A rich theoretical literature has returned to this question time and again, but the scope of the theory outside of product-based innovation has been unclear and robust multi-industry empirical evidence has been difficult to acquire. This paper makes progress on both fronts.

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[12] The unique exception I know of is Hollenstein and Woerter (2008), who separately explore 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).

[13] Current official statistics on e-commerce in the U.S. report all e-commerce sales by manufacturers or merchant wholesalers as B2B (U.S. Department of Commerce 2011). Yet, as early as 1988 – before diffusion of the commercial internet enabled huge waves of disintermediation and direct-to-consumer marketing – firms in manufacturing varied in their B2B vs. B2C focus: at least 11% of establishments surveyed in the Survey of Manufacturing Technologies (SMT) reported "Consumers" as their primary market (U.S. Department of Commerce 1989). After 1999, the distinction between buying and selling was eliminated from the official e-commerce statistics (U.S. Department of Commerce 2002).

On the theory side, it contributes a new conceptual framework that extends the innovation literature into the understudied but important area of *business process* innovation and clarifies how variation in adjustment costs can drive different patterns of innovation among leading firms, despite economies of scale. In particular, it considers the importance of complementary investments in the innovative process on the part of customers separately from internal factors such as process and organizational complexity.

The empirical contribution comes from applying this framework to a rich setting with data on specific uses of new internet technologies across a range of industries. The results yield a surprise: while adjustment costs related to internal factors help to explain resistance to e-selling adoption on average, they poorly explain the differential likelihood of adoption among leading firms. The need for customers to invest in the innovative process appears to be the biggest hurdle to leaders' engagement in this type of business process innovation. This finding stands in sharp contrast to prior work emphasizing the importance of internal capabilities in innovation and technological diffusion.

These findings are subject to certain limitations. Leveraging data collected by the U.S. Census Bureau overcomes many empirical challenges, such as accurately characterizing overall market and firm characteristics when the adoption behavior is only observed for a subset of firms. However, many key variables are only available for a single year. This prevents exploration into the precise timing of investment decisions. Moreover, 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 a technology becomes more mature and/or adoption becomes more widespread. Finally, the single cross-section of data makes it more challenging to control for firm characteristics whose omission might bias the empirical results. While 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.

In general, innovative activity focused on improving business processes warrants further attention by both theorists and empirical scholars. This paper takes a step towards 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 larger competitors through business-to-business process innovation.

The findings presented here can only hint at some of the long-term competitive implications. 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 – play in competitive strategy and market outcomes during periods of technological change.

Table 1. Definitions, Population Means, and Standard Deviations of Variables

Variable Name	Definition	Mean (est.)†	Std. Dev. (est.)
E-Sell	= 1 if the plant reports selling primarily over the internet; 0 else	.146 (.004)	.353
E-Buy	= 1 if the plant reports buying primarily over the internet; 0 else	.213 (.004)	.410
Intensive Internal IT	= 1 if the plant reports using networked computers in 2 or more of the following: design of the production process, production scheduling, production monitoring, test and acceptance of product; 0 else	.134 (.003)	.340
ERP	=1 if the plant reports having a fully-integrated Enterprise Resource Planning application; 0 else	.152 (.003)	.359
EDI	=1 if the plant reports having Electronic Data Interchange technology; 0 else	.144 (.003)	.351
LAN Network	=1 if the plant reports having a Local Area Network; 0 else	.469 (.005)	.499
Log Market Share	Logged share of total value shipped in 1997 by all plants in the focal plant's primary NAICS4 code	-9.53 (.019)	1.75
Share Catalog w/ Customers Online	=1 if the plant reports providing product descriptions or catalog information online (over any kind of network)	.092 (.003)	.289
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 else	.131 (.002)	.337
# of Plants	Total number of manufacturing plants belonging to the same parent firm in 1997	7.51 (.006)	22.2
Plant Diversity	Number of distinct primary product classifications (NAICS4) amongst all of the plants belonging to the same parent firm	2.50 (.020)	4.88
# MSAs	Total of Metropolitan Statistical Areas or counties (for rural plants) belonging to the same parent firm in 1997	4.24 (.054)	10.2
Age<10	=1 if the plant is 10 or fewer years old; 0 else	.287 (.005)	.453
Skill Mix	Share of non-production worker wages to total salaries and wages in 1997	.375 (.002)	.185

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

Table 2. Market Leadership & Internal Co-Invention Effects in E-Selling Adoption
Average Marginal Effects from Probit Estimates

	(1) Basic Controls	(2) Process Complexity	(3) Inter-dependence	(4) Org'l Complexity # Plants	(5) Org'l Complexity Diversity	(6) Org'l Complexity # MSA's	(7) IT Capabilities: Internal	(8) IT Capabilities: LAN	(9a) Market Share <=75%tile	(9b) Market Share >75%tile
Log Market Share	-.016*** (.003)	-.019*** (.003)	-.013*** (.003)	-.013*** (.003)	-.013*** (.003)	-.013*** (.003)	-.011*** (.003)	-.016*** (.003)		
Share Catalog w/ Customers Online		.099*** (.010)	.100*** (.010)	.100*** (.010)	.100*** (.010)	.100*** (.010)	.096*** (.011)	.095*** (.011)	.115*** (.016)	.049*** (.009)
Within-Firm Transfers			-.078*** (.009)	-.058*** (.011)	-.063*** (.011)	-.054*** (.011)	-.058*** (.011)	-.054*** (.010)	-.059*** (.010)	-.023*** (.007)
# Plants (in tens)				-.006*** (.002)			-.006*** (.002)	-.006*** (.002)	-.008*** (.002)	-.001 (.001)
# Primary Product Classifications (in tens)					-.018*** (.006)					
# MSA's (in tens)						-.014*** (.003)				
IT Capabilities							.063*** (.010)	.060*** (.009)	.060*** (.010)	
EDI							-.083*** (.011)	-.083*** (.010)	-.087*** (.011)	
Age<10	-.004 (.009)	-.005 (.009)	-.004 (.009)	-.004 (.009)	-.004 (.009)	-.004 (.009)	-.005 (.009)	-.007 (.009)	-.002 (.009)	
Skill Mix	.072*** (.019)	.065*** (.020)	.051*** (.020)	.049*** (.019)	.050*** (.019)	.049*** (.019)	.052*** (.019)	.039** (.019)	.048*** (.019)	
Industry Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
N	34,582	34,582	34,582	34,582	34,582	34,582	34,582	34,582	34,582	
Pseudo R^2	.0762	.0859	.0897	.0902	.0899	.0902	.0995	.1025	.0994	

Weighted maximum-likelihood bivariate probit estimation, reporting average marginal effects. Weights supplied by the U.S. Census Bureau to estimate population statistics for the U.S. manufacturing sector (roughly 400,000 plants in 1997). Robust standard errors are clustered by firm and included in parentheses. Significance levels are denoted as follows: *10%, **5%, ***1%. Columns 8a and 8b report the average marginal effects over both values of a dummy variable indicating whether the plant's market share was above the 75th percentile for its industry (NAICS4) in 1997.

Table 3. Cross-Process and Cross-Industry Comparisons
Average Marginal Effects from Bivariate Probit and Probit Analyses

	(1a) E-Buy	(1b) E-Sell	(2a) ERP	(2b) E-Sell	(3a) E-Sell B2C=0	(3b) E-Sell B2C=1	(5) E-Sell Apparel	(6a) E-Sell Low Competition	(6a) E-Sell High Competition
ln(MKTSHR)	.025*** (.002)	-.013*** (.002)	.034*** (.002)	-.019*** (.003)	-.027*** (.003)	.011* (.006)	.023*** (.007)	-.012*** (.004)	-.036*** (.005)
Share Catalog w/ Customers	.070*** (.009)	.034*** (.007)	.031*** (.006)	.070*** (.009)			.057 (.038)	.133*** (.020)	.124*** (.023)
Within-Firm Transfers	-.004 (.007)	-.031** (.007)	.036*** (.008)	-.049*** (.010)	-.037*** (.010)	-.071*** (.014)	-.060*** (.034)	-.055*** (.010)	-.032** (.015)
# Plants (tens)	.001 (.001)	-.004*** (.001)	-.003** (.001)	-.004*** (.002)	-.009*** (.002)	-.011* (.006)	-.022 (.016)	-.009*** (.002)	-.008*** (.003)
IT-intensive (internal)	.057*** (.007)	.018*** (.006)			.098*** (.013)	.019 (.027)	.065* (.035)	.068*** (.017)	.098*** (.019)
LAN			.101*** (.006)	.033*** (.008)					
EDI	.042*** (.007)	-.058*** (.007)	.078*** (.005)	-.084*** (.009)	-.064*** (.009)	-.065*** (.020)	-.114*** (.041)	-.072*** (.010)	-.060*** (.012)
AGE<10	.032*** (.008)	-.012** (.006)	.005 (.006)	-.006 (.008)	-.003 (.010)	-.028 (.024)	-.019 (.029)	.000 (.013)	-.017 (.014)
SKILLMIX	.025 (.017)	.025** (.013)	-.034** (.014)	.027* (.017)	.107*** (.019)	.091** (.043)	.035 (.048)	.070*** (.025)	.111*** (.026)
Industry Controls	Yes		Yes		No	No	No	No	No
N	34,582		31,319		31,652	2,930	797	17,588	16,994
ρ	.3803		.1085						
Wald X^2	1949		3650						
Pseudo R^2					.0535		.1079	.0540	

Weighted maximum-likelihood bivariate probit (Columns 1a – 2b) and probit (Columns 3a-6a) estimation, reporting average marginal effects. Robust standard errors are clustered by firm and included in parentheses. Significance levels are denoted as follows: *10%, **5%, ***1%. Columns 3a and 3b report the marginal effects averaged over both values of a dummy variable indicating whether the plant's primary industry classification is "business-to-consumer" – i.e., in an industry with 75% or more of its output going to Final Use according to the Bureau of Economic Analysis (www.bea.gov). Columns 6a and 6b report the marginal effects averaged over both value of a dummy variable indicating whether the plant's primary industry classification has a 10-year weighted mean Lerner Index equal to or greater than the mean for all 3-digit SIC codes in the U.S. Manufacturing sector.

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