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The Effect of Market Leadership in Business Process Innovation: The Case(s) of E-Business Adoption

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Abstract:

This paper empirically investigates how market leadership influences firm propensity to adopt new business process innovations. Using a unique data set spanning roughly 35,000 plants in 86 U.S. manufacturing industries, I study the adoption of frontier e-business practices during the early diffusion of the commercial internet. Theory predicts that firms with greater market share will be more likely to adopt innovations that build on their existing strengths, while they will resist more radical technological advances. While prior work primarily focuses on product innovation, I extend the logic into the business process setting to find that leaders were far more likely to adopt the incremental innovation of internet-based e-buying. However, they were commensurately less likely to adopt the more strategically sensitive and complex practice of e-selling. This pattern is remarkably robust, holding across a wide range of industries and controlling for factors such as productivity and related technological capabilities. The results are explicated by a framework I develop for understanding the drivers of this behavior and making it possible to classify business process innovations as radical or not. While greater market share promotes adoption of all types of business process innovations, this effect is outweighed by additional co-invention and coordination costs whenever a technological advance address strategically sensitive and complex business processes that must also span the firm boundary.

JEL classifications: L21, O33, D24, M15

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1. Introduction

Identifying when market leaders will embrace technological progress has been a long-standing question in innovation and strategy research. As far back as Schumpeter (1934, 1942), scholars have debated the impact of market position on innovation – are large incumbents or small entrants more likely to advance technological change?

The answer has far-ranging implications for technology diffusion, corporate strategy, and industry evolution. If leading firms can raise the bar for competitors by pursuing innovative products and processes, then their industries may advance technologically while remaining concentrated among dominant firms. Innovation in this scenario becomes a tool for leading firms to maintain or improve their competitive position. On the other hand, resistance to new technological opportunities may invite incursions by entrepreneurial rivals, causing market leaders to fall behind or eventually be replaced. Thus, understanding the relationship between market leadership and the adoption of new technologies becomes central to an appreciation of how firms may maintain or gain competitive advantage over time.

A large theoretical literature in both economics and strategy has explored how firms of different sizes and market positions will respond to innovative opportunities. Yet consensus remains elusive. According to prior work, larger, dominant firms have both more to gain and more to lose from disrupting the status quo. They have organizational advantages that smaller firms may lack, but also greater inertia. Predicting the ultimate relationship between market share and innovation ends up depending on a wide range of modeling assumptions – many of which are difficult to distinguish in practice. Relevant empirical tests remain likewise inconclusive, due in part to econometric problems and a tendency toward single-industry studies or anecdotes that are difficult to generalize.

The goal of this paper is to empirically explore *whether* market leaders are most likely to adopt business process innovations, *when* this is most likely to happen (or not), and *why*. In search of a robust and generalizable answer to the first question, I leverage an empirical context that cuts across a broad range of industry settings. The data come from a survey conducted by the U.S. Census Bureau in 1999 of roughly 35,000 plants in 86 manufacturing industries. Designed to measure the use of information technology (IT) among manufacturers, this survey provides an opportunity to observe IT-enabled process innovation amongst a representative sample of firms. I focus on the adoption of frontier e-business practices during the early diffusion of the commercial internet, in particular internet-based e-buying and e-selling.

Understanding *when* market leaders might have an advantage in business process innovation requires a more precise theoretical understanding than is easily sifted from existing work. To gain clarity, I leverage insights from the economics and strategy literature on incremental versus radical innovation (e.g., Henderson 1993). Fundamentally, this framework recognizes that the *nature* of an innovation matters. Changes that reinforce the strategic and organizational advantages of incumbent firms are more likely to be adopted by them. The greater the incumbent's market share, the greater the propensity to adopt these incremental advances. In contrast, radical changes that threaten existing market position – for instance by cannibalizing sales or disrupting strategically sensitive activities – are commensurately less attractive for leading firms.

Testing whether this distinction holds true in the business process setting presents particular challenges. To begin, existing research on innovation and technological change has focused overwhelmingly on the invention and commercialization of new products. Process innovation, by comparison, has received far less attention (Rosenberg 1982), particularly in the scholarly literature. *Business* process innovation, has received even less, despite being an important feature of corporate strategy over the past 20 years. In addition, very little empirical work to date has been able to distinguish between incremental and radical innovations in practice, and only in very limited contexts.

My research setting has the unique advantage of allowing me to observe the reactions of the same firms at the same time to both incremental and radical innovations – and thus compare the market share effects between the two to establish the importance of this distinction. This test depends critically, however, on being able to map the theory on incremental vs. radical innovation into the novel business process setting.

My approach relies on first developing a basic framework for distinguishing radical business process innovations from incremental ones, and then integrating it with an in-depth qualitative analysis of the phenomenon. I argue that the higher the strategic importance and complexity of the underlying business process to be affected, the more radical any proposed change will be Careful qualitative analysis reveals that, despite a reliance on a common technology platform, e-buying and e-selling in 1999 differed dramatically along these dimensions. At the time of the Census survey, e-buying concerned electronic procurement of highly standardized materials such as maintenance and office supplies that, while they impacted the cost structure of the firm, were not unduly complicated to acquire or strategically sensitive for the majority of manufacturing firms. E-selling, by contrast, governed not only a far greater complexity of products but also critical business processes such as sales and customer management that faced disruption and channel conflict in the switch to internet-based sales. As such, e-buying constituted a relatively incremental process innovation, while e-selling was far more radical.

I find robust statistical evidence consistent with the hypothesis that market leaders would pursue the incremental e-buying innovation. In this large, multi-industry sample of firms, firms with the greatest market shares, sales and profits were significantly more likely than laggards to adopt the internet as their primary platform for online procurement

I find the exact opposite in the case of e-selling: market leaders were far less likely than smaller or less-successful competitors to embrace internet-based sales. While many of the same influences (such as economies of scale) that promote e-buying adoption by leading firms ought to apply in the e-selling case, the economic and/or organizational disruption of this innovation is sufficient to induce a commensurately negative relationship between market leadership and adoption likelihood. Moreover, this pattern holds even controlling for potentially confounding factors such as other related IT investments and underlying productivity. This result is consistent with the hypothesis that market leaders will be less likely to adopt radical business process innovations.

Thus, this paper contributes robust, multi-industry evidence that market leaders are more likely to adopt certain types of innovations and sheds light on precisely when this is likely to happen (or not). Moreover, the process of refining and extending existing theory into the novel business process context yields the insight that many of our product-based intuitions transfer well to the business process setting: market leaders are far more likely to adopt incremental business process innovations, while radical changes may encounter resistance amongst the most successful firms.

With evidence on *whether* and *when,* the remaining question is *why* – what specific attributes of innovations or their potential adopters lie at the root of this behavior? Additional analysis reveals important insights about the innovations themselves. The qualitative differences between e-buying and e-selling are consistent with my proposed definition of business process innovations as either incremental or radical based on whether the process was strategically sensitive (and therefore risky to change) and/or relatively complex (and therefore costly to change). However, an additional criterion of "radicalness" proves necessary: whether the underlying business process spans the firm boundary. Leveraging the rich Census survey, I compare market share effects across a wide range of e-business processes with different characteristics. My findings support the proposition that a *combination* of complexity, strategic sensitivity and boundary-spanning create the particular challenge observed for market leaders in the case of e-selling – and that all three may be required to make a business process innovation truly radical for leading firms.

This enhanced understanding of *why* market leaders may enjoy certain advantages or face additional challenges in business process innovation has important practical implications. Being able to apply what we know about the innovative behavior of firms requires the means to distinguish, *ex ante*, whether a proposed change lies on the incremental or radical end of the spectrum. While far more work – both empirical and theoretical—is needed to place different types of innovations in a comprehensive taxonomy, the suggestive evidence on what makes e-selling radical is a step in this direction. My results indicate that, in cases where firms must coordinate complex and strategically important activities throughout a larger organization, across more establishments, while spanning the firm boundary, adoption will tend to take place primarily among smaller firms. This inter-firm coordination challenge is an important strategic consideration as businesses grow ever more dependent on the performance of their extended value chain for success. Lagging firms may discover new opportunities to leapfrog their larger competitors using certain business-to-business process innovations and IT-enabled supply chain relationships.

This paper proceeds as follows. Section 2 develops the theory and places this paper in the relevant literature. Section 3 delves into the details of the phenomenon, forming the link between the context and the hypotheses. Sections 4 and 5 present the data and econometric model, respectively. Section 6 reports on the empirical the drivers of e-business adoption. Section 7 refines the definition of radical business process innovation. Section 8 concludes.

2. Literature and Theory Development

2.1 Overview

A rich body of work in both economic and organizational theory addresses the question of how incumbent firms with large market shares will react to –and participate in –technological change. While the inquiry dates back at least to Schumpeter (1934, 1942), Arrow's seminal (1962) theory that existing monopolists will resist innovating to avoid cannibalizing existing sales sparked a surge of research into the effects of market structure and firm size on innovative activity.[1] The results of these models predict highly contradictory outcomes depending on a range of considerations such as the degree of competition (Boone 2000, Aghion et al. 2005), the availability and use of property rights (Dasgupta and Stiglitz 1980) or the nature of the discovery process (Reinganum 1983, Doraszelski 2003) – many of which are remarkably difficult to measure in practice (Gilbert 2006).

Recent theoretical advances have focused less on market structure itself than on a firm's position *in* the market (e.g., in terms of market share or cost effectiveness) and how it influences the incentives to innovate. The most recent and generalizable models (e.g., Athey and Schmutzler 2001) predict "increasing dominance", whereby leading firms invest to shore up or improve their favorable market position, in a wide variety of cases. However, exceptions do exist, and cogent arguments can be found predicting a greater propensity to innovate among both market leaders and lagging firms.

The related empirical literature, likewise, is "notable for its inconclusiveness" (Cohen and Levin 1989). In part, this is due to econometric problems such as poor treatment of industry heterogeneity and

[1] Reviews of this sizeable literature are provided by Kamien and Schwartz (1982), Baldwin and Scott (1987), Reinganum (1989), and Gilbert (2006).

sample selection bias.[2] Additionally, a failure to distinguish product from process innovation or address the simultaneous determination of market structure and innovation have limited the contribution of this work (Gilbert 2006). Finally, far less attention has been paid to the adoption of existing innovations than to R&D expenditure or patenting behavior, despite well-known problems with these latter measures of innovative activity (Blundell et al 1999).

The dearth of clear predictions and evidence is even greater when it comes to considering the adoption of business process innovations. Existing innovation research has focused overwhelmingly on the invention and commercialization of new products.[3] Process innovation, by comparison, has received far less attention (Rosenberg 1982), particularly in the scholarly literature. *Business* process innovation, has received even less, despite being an important feature of competitive strategy over the past 20 years.

This class of innovative activity warrants closer attention in light of theory and evidence that process innovation and its drivers may differ in important ways from innovation geared toward new product introduction. Factors external to the firm such as product lifecycles (Utterback and Abernathy 1975), degree of competitive pressure (Boone 2000) or customer requirements (Adner and Levinthal 2001) are believed to emphasize process innovation over product enhancement in certain cases. Internal factors such as scale of output (Cohen and Klepper 1996, Klepper 1996) and organizational routines and priorities (Henderson et al. 1998) may also create incentives to follow different innovation paths. Firms that excel in one may struggle with the other, with important implications for competitive outcomes.

Given the state of the literature, a key challenge of my research design is to distill meaningful testable hypotheses that fit well in the business process setting. To overcome this challenge, I leverage insights from the economics and strategy literature on radical versus incremental innovation to distinguish predictions based on the nature of the innovation in question. To supplement the theory development, I also borrow insights from prior economics research on process innovation.

2.2 Incremental vs. Radical Innovation

According to prior work, leaders will be more likely than lagging firms to innovate when it enhances or builds on their existing activities. While this ought not to apply to innovations that are "drastic" (Arrow 1962) or "radical" (Henderson 1993) in the sense that they render existing technologies or knowledge obsolete, theory predicts leading firms will tend to enjoy both greater incentive *and* greater ability to pursue incremental innovations than will smaller rivals (Henderson 1993).

[2] A notable exception is Blundell, et al (1999) which finds a strong positive relationship between the market share and stock market value of publicly traded U.K. firms and their incentives to patent their discoveries.
[3] Exceptions are discussed in section 2.

On the incentive side, economics and strategy research emphasizes the strategic benefits to a leader of maintaining its dominant position in the face of technological change. Because a large firm with some degree of market power will enjoy higher rents per unit of sales than will a smaller firm, it will have greater marginal incentive to protect that power. Thus, leaders will be more likely to invest in a new technology (such as a new process innovation) that allows them to lower production costs and thus price more aggressively in the product market (Fudenberg and Tirole 1984, Sutton 1991) or otherwise pre-empt potential rivals from entering the market (Gilbert and Newbery 1982).[4]

Strategic interactions aside, other economics research suggests that straightforward economies of scale will increase the benefits of process innovation among larger firms relative to smaller ones (Cohen and Klepper 1996, Klepper 1996). This is because they can spread fixed investment costs over a greater volume of sales and better appropriate the value of lower production costs in their own operations. The greater the market share, the greater this benefit. Thus, barring any adjustment costs that increase disproportionately with firm size, market leaders will tend to enjoy higher net benefits from process innovation.

In addition to being more willing, leaders will tend to be more *able* to pursue incremental innovations. A rich organizational theory literature argues that firms tend to develop routines (Nelson and Winter 1982) and information filters (Arrow 1974) based on prior experience that embody organizational knowledge and fundamentally condition how they react to changes in their environment. As a result, the experience and knowledge gained over a larger scale of activity and/or over time may make it easier for larger incumbents to identify and pursue innovations that build on existing advantages and extend existing knowledge (dubbed "competence-enhancing" innovations by Tushman and Anderson, 1986). Larger firms may also have invested more in resources (Wernerfelt 1984) or capabilities (Barney 1991) that enable them to more effectively exploit incremental advances.

Combining incentives and abilities together, firms with larger market shares have significant advantages over smaller firms when it comes to incremental process innovation. While additional details of the setting will be needed to determine which observable business process changes fall into this category of incremental innovation, the basic hypothesis to be tested is the following:

> <u>*Hypothesis 1*</u>*: Firms with larger market shares will be systematically more likely to adopt incremental business process innovations, all else equal.*

4 Athey and Schmutzler (2001) develop a very general model of how market position influences investment in cost-reducing or demand-enhancing technology. Their contribution is a framework that subsumes much prior work as special cases and predicts leading firms will be more likely to invest under a wide range of common assumptions.

In sharp contrast, radical innovations pose greater problems for larger firms. Innovations that threaten or destroy firms' existing competencies (Tushman and Anderson 1986), that are organizationally "radical" (Henderson 1993, Henderson and Cockburn 1994) in the sense that they demand entirely new knowledge or ways of processing information, or that are otherwise disruptive (Christensen 1997) to their existing product market offerings, will face greater resistance. Larger firms that have survived longer or grown faster than rivals will tend to have made greater investments in organizational routines, procedures, and resources that embody their acquired know-how and lower the costs of day-to-day operations. Thus any innovation that requires the removal or replacement of those existing organizational capabilities is disproportionately more difficult and/or costly for larger firms.

Economic theory weighs in here, too, in terms of the opportunity costs larger firms face due to disruption of its production. To the extent that larger firms may enjoy higher rents per unit of production due to their greater market power, any disruption or replacement of existing sales due to the implementation of a new technology or process will be relatively more costly for larger firms than for smaller ones. Thus, we have the complementary hypothesis:

> <u>Hypothesis 2</u>*: Firms with larger market shares will be systematically less likely to adopt radical business process innovations, all else equal.*

2.3 Classifying Innovations

While a useful conceptual tool for grappling with the contradictory theory literature, this distinction between incremental and radical innovation has found limited empirical support to date. Meaningful differences can be found only in single-industry empirical studies in food packaging (Ettlie et al. 1984), footwear manufacturing (Dewar and Dutton 1986), and the photolithographic alignment equipment industry (Henderson 1993). Other, multi-industry empirical work has failed to find evidence of this distinction (Blundell et al. 1999).

One reason for the lack of systematic cross-industry evidence may be the challenge involved in defining a given innovation as either incremental or radical in a way that transcends a particular industry or firm context. Prior innovation research is of limited definitional help in the business process context because it either focuses on product innovation[5] or tends to equate process innovation with incremental change (e.g., Cohen and Klepper 1996, Klepper 1996, Bonanno and Haworth 1998, Boone 2000). Notable exceptions include Tushman and Anderson (1986), Dewar and Dutton (1986), and Sull et al. (1997), which consider the possibility that process innovation can be radical and thus threatening to market

[5] See Pisano (1997) for a notable exception.

leaders. However, these exceptions are largely based on industry-specific anecdotes and tend to focus on process innovations that dramatically shift the product attributes that are achievable (e.g., Pilkington float glass in Tushman and Anderson 1986, or radial tires in Sull et al. 1997) and/or represent radical departures in the mechanical or scientific knowledge required by a firm. Business process innovations, in contrast, can quietly transform internal firm operations with little or no visible impact on product-market offerings and interactions. This makes them extraordinarily difficult to classify, *ex ante*.

My empirical exercise requires, however, that I do just that. The first basis for classification I consider is the strategic sensitivity of the business process undergoing transformation. In order for changes to a process to pose the substantial risks or costs described in the radical innovation literature, the underlying process must first be strategically important to the firm. The opinion of experts in the practice of IT-enabled process innovation also supports the notion that these core activities are the hardest ones to change (Davenport 1993). While a given business process may vary in strategic importance from firm to firm, we may be able to classify certain processes as *typically* more sensitive or not across a broad sample of organizations.

Another criterion – complexity – comes from prior research on the economics of IT adoption. The adoption of information technology quickly becomes an exercise in business process innovation when significant investments in time and money are required to match the technology to internal firm activities – or, more importantly, to match internal firm activities to the technology. Often, these undertakings entail substantial uncertainty and risk for the adopting firm, particularly if they touch on strategically sensitive processes that determine a firm's competitive advantage. Evidence suggests that these "co-invention" costs and risks are systematically higher wherever there is a greater complexity of processes (Bresnahan and Greenstein, 1996). Thus changes to more complex firm processes ought to be more radical than simpler adjustments.

A final dimension of this classification concerns the organizational structure of the underlying business process. Managing change within an organization is sufficiently challenging when the primary stakeholders function with the boundaries of the same firm. Hierarchy and shared culture help facilitate both decision-making and the implementation of process innovations. These advantages do not exist, however, when core business processes cross firm boundaries. When core activities of the firm require tight integration with other members of the value chain – especially customers, then the costs and risks associated with redesigning them increase dramatically. The greater the number of inter-firm linkages, the greater the difficulty (Davenport, 1993).

These criteria do not provide an exhaustive definition of radical business process innovation. However, they are both suggestive and prove useful in the next section, where I delve into the e-business phenomenon to understand the nature of the e-buying and e-selling innovations and how they map into my core hypotheses. The differences between e-buying and e-selling in terms of their degree of strategic importance and complexity are easiest to determine. Because both e-buying and e-selling span the firm boundary to some degree, I provide additional analysis in section 7 to make the case for why this third criterion constitutes a necessary but not sufficient component of "radicalness" in business process innovation.

3. Phenomenon: IT-Driven Business Process Innovation

At the highest level, this study investigates how incumbents of different sizes reacted to the new opportunity offered by the diffusion of the commercial internet to conduct business-to-business (B2B) transactions online. Superficially, "e-commerce" or "e-business" entails moving the communications and transactions associated with buying and selling goods from traditional technologies – such as telephone, fax, and face-to-face interactions – to an electronic communication network such as the internet. More fundamentally, the shift to electronic processes *automates* the management of transactions for purchasing or selling goods between firms. The primary benefit of automation is that it guarantees a particular process flow will be executed with speed and consistency for every transaction.[6]

Automation, however, can be a double-edged sword. Because it requires standardized processes and modalities of communication, it often requires tremendous coordination and negotiation to decide what those standards should be. The more core the process and/or the more complex, the harder automation becomes (Davenport 1993). In order to enjoy economies of scale based on automation, uniformity of practice throughout an organization becomes necessary. However, this can be disruptive to existing routines and organizational structures and increase pressure to "get it right" the first time, which can promote both delay and disruption during the implementation process (Edmondson et al. 2001).

Moreover, when the process flow to be automated crosses firm boundaries, as it tends to do in e-business, this creates opportunities for conflict and re-negotiation of contracts between supply chain partners (Varon 2001). At the very least, it requires tight coordination with business partners, not all of whom will have the same needs and expectations (Davenport 1993). As will become clear, strong anecdotal evidence suggests that automation benefits were straightforward for e-buying, but that the costs and potential risks were much higher for e-selling in 1999.

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[6] For instance, an oft-cited value of e-buying applications is that they reduce costs of goods sold (COGS) by preventing "maverick buying", which can involve a cost premium of 15-27% (AMR Research 1999a) Essentially, the business process rules embedded in e-buying applications prevent purchases from unapproved vendors or block purchase orders that exceed certain tolerances (e.g., price), keeping costs under control; automated and centralized reporting also improve oversight. On the sell-side, automation can reduce costs associated with order inaccuracies such as returns and other customer service expenses (AMR Research, 1999b).

Before moving on to a discussion of frontier e-business practices, it is important to note that business-to-business electronic commerce did not originate with the internet. Electronic Data Interchange (EDI) already existed to allow businesses to exchange documents such as purchase orders and invoices.[7] While both the internet and EDI provided a platform for inter-firm communication and transactions, they had significant differences in terms of how costly they were to implement and update. Most significantly, unlike the ubiquitous open-standard internet platform, EDI was a much more expensive proprietary technology, typically controlled by a dominant supply chain partner (e.g., General Motors in the automotive supply chain), and useful primarily for very simple and highly standardized communications.[8] Thus, for firms that already had adopted EDI to automate some or all of their buying and selling processes, the internet standard presented both the opportunity *and risk* of reformulating and renegotiating those firm-to-firm transactions. While the focus of this paper is on the early stages of internet-based e-commerce diffusion[9], I take care to control for the potential role of EDI in influencing the empirical results (see section 6).

While internet-based e-buying and e-selling share a common technology platform, at the time of this study they addressed fundamentally very different business practices. [10] E-buying applications in 1999 were focused on enabling online procurement of maintenance, repair, and operations (MRO) goods such as lubricant, spare parts, cleaning supplies, office supplies, etc. – i.e., anything consumed in the production process not directly put into finished goods. This *indirect procurement* is distinct from the procurement of specialized materials and parts for direct use in production (appropriately termed *direct procurement*). Indirect purchasing centers on spot transactions involving highly standardized goods.

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[7] The U.S. Census estimates that, by 2000, the majority of value exchanged online in the US was over EDI networks (US Department of Commerce 2000).

[8] The drawbacks of EDI were captured succinctly by one observer: "EDI has limitations, including an inflexible format that makes it difficult to use for any but the most straightforward transactions. Many small companies never adopted it because it was expensive. Much of the newer e-commerce software uses XML — grammatical rules for describing data on the Web — as its standard for data exchange. Though the software may also handle EDI transactions, XML allows for more variety in the information companies exchange and was designed for open networks."(Varon 2001).

[9] Information systems scholars consistently emphasize the greater potential of internet technology to transform business processes within and between firms. For example, "Internet technologies may induce large-scale transformations within an organization as well as in its relationships with customers and suppliers. Thus, while there is some evidence of economic impacts from IT such as EDI, it is not clear whether this can be directly extended to the internet-based electronic business. (Zhu and Kraemer 2002).

[10] While e-commerce has garnered increasing attention (particularly in the information systems literature – see Straub et al. 2002 and Zhu and Kraemer 2002), there is also very little attention paid to heterogeneity in the technologies and business practices subsumed by labels such as "e-commerce" or "e-business. 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).

While cost savings from electronic indirect procurement were significant,[11] strategically, this remained a relatively straightforward and peripheral activity for the typical manufacturing plant.

Direct procurement, on the other hand, tends to take place in the context of long-term relationships between supply chain partners and involve a much greater complexity of items with much more stringent performance requirements. At the time of the Census survey, however, software solutions for direct purchasing over the internet were not widely available.[12] Thus, e-buying for the purpose of this study is equivalent to internet-based indirect procurement.

In sharp contrast to e-buying, e-selling applications in 1999 focused primarily on finished goods (e.g., computers, clothing, consumer packaged goods, etc.) for sale to distribution partners and some end users. As a result, these solutions tended to be more varied and far more complicated to implement for nearly all firms. One analyst report captures the nature of e-selling solutions at the time: "What the projects lack in simplicity they make up for with diversity," (AMR Research 199b).

Moreover, the goods governed by the e-selling process tended to involve multiple firm activities such as sales and production planning, and touched on strategically sensitive issues such as brand image and customer relationship management. They also involved distribution partners in a very intimate way, affecting channel and supply chain strategy decisions. During the early diffusion of e-selling, there were widespread concerns about channel conflict and examples of outright rebellion on the part of channel partners (Gilbert and Bacheldor 2000).

3.1 E-Buying vs. E-Selling in 1999: Incremental vs. Radical Innovation

How do these differences help us distinguish whether the e-buying and e-selling innovations were incremental or radical? The evidence is clear that e-selling was more challenging and risky to implement than e-buying in almost every way (AMR 1999a & b). But, in order to test our hypotheses regarding how market leaders will respond to business process innovations, we need to understand which challenges of e-selling would *differentially* impact larger firms compared to smaller firms.

[11] According to AMR Research, "The cost to process an indirect purchase can be between $75 and $175 per request. Indirect [e-buying] applications automate much of the process and save significant personnel time…Early feedback from indirect [e-buying] projects indicates an average order processing cost of between $10 and $15." (AMR Research 1999a).

[12] At the time, Ariba, Commerce One and similar vendors of "procurement" applications had well-defined offerings for MRO procurement. Firms such as Mercado and QRS specialized in meeting the needs of retailers to manage the flow of finished goods and had begun to extend their offerings into manufacturing. But very little headway had been made in terms of offering a solution that could effectively manage direct procurement (AMR Research 1999b).

Qualitative evidence from analyst and press coverage at the time suggests that internet-based e-selling was radical according to the first two criteria advanced in section 2 in that it involved both strategically sensitive and complex business activities. Quite different from e-buying, which was less sensitive and more straightforward, e-selling actually forced adopters to give up, replace, or jeopardize processes and/or relationships that had formed the basis of prior success – both internally and externally. Internally, the demands of automation placed potential adopters between two costly alternatives: replace existing core processes with standardized "off the shelf" functionality offered by software vendors, or else invest in customizing or developing their own e-selling software. Yet, these processes often embody key aspects of what firms consider to be their competitive advantage. Thus, many chose a hybrid approach involving both a high level of customization of available products and some business process reengineering (AMR 1999b) – in short, "co-invention"(Bresnahan and Greenstein, 1996). A recurring theme at the time was the significant technical challenge and cost in terms of time and money to implement new e-selling capabilities.[13]

Externally, e-selling adoption entailed even greater costs and risks in terms of business process disruption. As part of the implementation process, trading partners had to collaborate on what the online sales process should look like, what types of data ought to be exchanged, where control for certain activities would lie, etc. Yet determining how transactions and process flows should operate as they crossed the firm boundary opened up existing contracts for renegotiation and often proved to be a risky and challenging undertaking (Davenport 1993).[14] Online sales also often replaced some fraction of offline transactions – particularly in the early stages of adoption when firms were exploring how to conduct business over the internet with their existing customers (AMR 1999b). Channel conflict was cited as the number one concern of firms considering online sales at the time (Gilbert and Bacheldor 2000). Moreover, all of these costs tended to scale with the size and scope of a firm's operations and customer relationships.

In addition, e-selling adoption may have upped the ante in terms of the competencies needed to succeed in the market. For instance, reduced order cycle times through real-time internet-based exchange tended to raise expectations that rapid order execution would be met with equally rapid fulfillment. If this was not already a strong competency of an existing market leader, the challenges of developing and scaling new capabilities in this area could prove more costly for larger firms and threaten their market advantage.

[13] Even the notable successes, such as the launch of milpro.com by tool-manufacturer Milacron, Inc. in January of 1999, were notably costly. The firm spent a dollar in customization and consulting for every dollar of the software license, involved more than 120 people from all over the company, and required 10 months to launch (Schultz 1999, Teach 1999).

[14] For firms with EDI, it meant replacing their existing proprietary network transactions.

In terms of testing our hypotheses about market leadership, complexity is also an important consideration in this context because it is both intuitively and empirically related to size.[15] For the reasons discussed in section 2, larger incumbents with more entrenched, strategically important, or complex selling processes likely found the costs of disrupting or changing those proprietary workflows to be disproportionately higher than did smaller firms. Doing so across multiple lines of business and multiple locations would make a given e-selling initiative that much more radical for an adopting firm.

Thus, in well-defined ways, e-buying represented relatively incremental change for adopting firms, allowing them to cut costs in a straightforward, low-risk way. E-selling, on the other hand, represented a radical process innovation with real strategic risks to incumbent firms and costs that tended scale with a firm's size and complexity. These qualitative differences are reflected in the large-scale data on e-buying and e-selling adoption presented in the next section, where e-buying enjoyed a somewhat higher degree of diffusion. The empirical test of interest, however, is to see whether e-selling was differentially more costly for market leaders than for smaller rivals, influencing not only the speed but the *distribution* of adoption in ways that have strategic implications. This is the focus of the remainder of the paper.

4. DATA

An advantage of my research setting is that it addresses many of the known problems with prior empirical research in this area. The large sample allows for rich industry controls to help isolate the behavior of interest. The Census survey exclusively addresses the adoption of non-patentable process innovations, going beyond settings that mix product and process innovations together and leveraging an important but understudied measure of innovative activity. And, finally, sample biases are obviated by a data collection and reporting process specifically designed to generate representative estimates of a large swath of US firms and economic activity.

4.1 E-Business Practices

The dependent variables capturing e-business adoption come from the 1999 Computer Network Use Supplement (CNUS) which was mailed to a 10% sample of all manufacturing plants in the United States, with extra sampling weight assigned to larger manufacturing plants. The approximately 35,000 plants included in this sample accounted for more than 50% of manufacturing employment and output in the United States.

[15] Evidence of the empirical correlation between the size of US manufacturing establishments or firms and operating complexity in terms of the number of distinct product lines is provided by Gollop and Monahan (1991) and McElheran and Riggs (2010).

The CNUS contains extremely detailed information on plant use of a variety of e-business practices (see http://www.census.gov/econ/estats/1999/manufinal/MA-1000(EC).pdf for the publicly available survey instrument). Examples range from e-mail to sharing online catalogs to network-enabled vendor managed inventory practices. In particular, plants identify whether or not they place or accept orders for goods or services over a network and whether the primary network for doing so is the internet. Establishments that report online purchases taking place primarily over the internet are coded as having adopted e-buying, similarly for e-selling.[16]

A nice 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 pilot projects with true business process innovation requiring substantial investment and co-invention by adopters.

Summary Statistics

According to this snapshot taken in 1999, the reach of electronic business capabilities appears wide: e-commerce takes place in every manufacturing subsector and at every point of the size distribution. An estimated 26% of manufacturing plants either place or accept orders over the internet at the time of the survey. Table 1 contains both observed frequencies in the sample and population estimates based on sampling weights:

Table 1. Adoption of E-Business in US Manufacturing

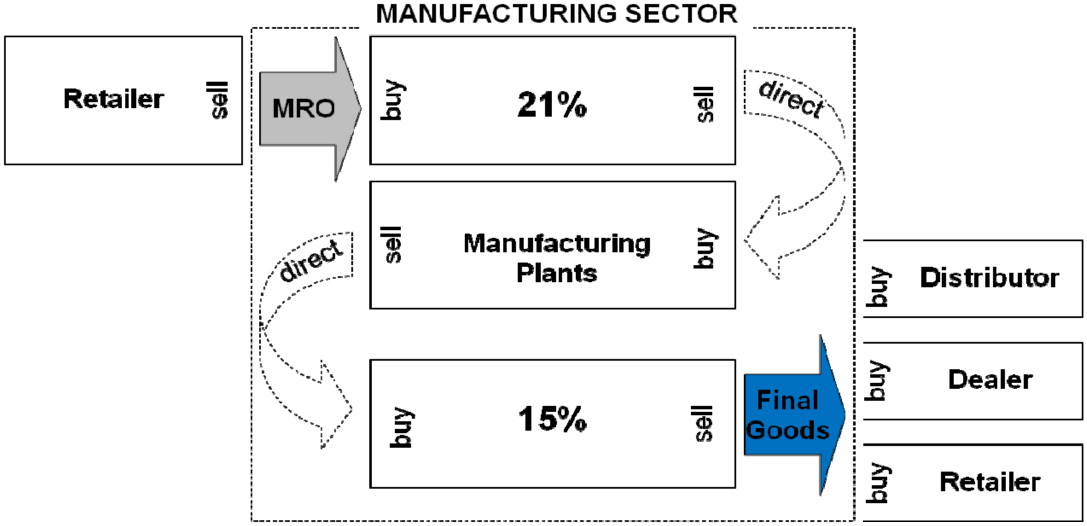
Internet-based E-business Practice	**% of Sample**	**% of Plants in Population (estimated)[17]**
E-buying	26%	21%
E-selling	10%	15%
E-buying or E-selling	31%	29%
E-buying & E-selling	5%	6%

[16] Note that this definition will exclude 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.
[17] These numbers represent responses from plants for which production information in 1997 is also available, weighted using the Census Bureau's ASM sampling weights.

Even these high-level summary statistics reveal a great deal of heterogeneity in the use of internet technology. Plants tend to specialize in their e-business practices: only 5-7% both accept and place orders over the internet (this goes up to only 14% when all network platforms is included). Also, industries vary in terms of how prevalent the use of e-commerce is (see table 9). Computers and Electronics and Printing have the highest penetration. In the former, roughly 38% of plants place and 21% accept internet orders; in the latter the percentages are 32% and 34% for buying and selling, respectively. Apparel is a trailing industry with just around 7% for both e-buying and e-selling. Some industries lean more towards one than the other. Only 6% of Textile Products plants place internet orders, but over 16% accept them.

Another important difference between e-buying and e-selling in the Census sample concerns the fact that the e-buying and e-selling adoption observed in the survey do not represent mirror images of the same 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 typically make up the customer-side of the e-selling transaction also lie outside the manufacturing sector. (See Figure 1, which graphs the buying and selling transactions along the supply chain, with a rectangle framing the part of the chain sampled in the Census survey.). Thus, the e-buying and e-selling activities in this study concerned completely separate firm activities (though not necessarily independent investment decisions, which I address in the econometric model in the next section).

Figure 1. Differences between E-Buying and E-selling in the CNUS Survey



Solid arrows represent electronic transactions that were feasible between supply chain members at the time: e-buying of MRO goods and e-selling for Final Goods, as described in section 3. The empty arrows for direct goods signify the lack of commercially available direct procurement software solutions in the late 1990s. Direct procurement and sales took place in some fashion among manufacturing firms, but not using commercial available internet solutions. The frame around the manufacturing sector captures the fact that the survey does not cover the sell-side of the MRO e-buying transaction (taking place in the Retail sector), nor the buy-side of the final goods e-selling transaction (also outside of Manufacturing). Due to these restrictions on electronic business solutions at the time and manufacturing-centric sample, e-buying and e-selling thus represented separate business processes in the CNUS survey.

4.2 Leadership

The key explanatory variables capture the salient features of market leadership. Market share being the traditional definition, I make use of data from the 1997 Census of Manufactures (CMF) on the entire universe of manufacturing plants in the United States. Conducted every five years by the US Census Bureau, this survey captures rich operational details including the value of all shipments from the plant and the costs of inputs such as materials and wages. Thus, it is possible to accurately measure the value of shipments in each industry and the share of that value shipped by every plant in the data set. I identify the relevant market as the total value of shipments coded as primary product shipments in the same 4-digit NAICS industry code as the plant of interest.[18] Plant market share is the percentage of this market shipped from the individual plant.

[18] All core results are robust to using a 6-digit NAICS industry definition.

In order to relate to existing work that typically focuses on output at the *firm* level, I also calculate market share for the parent firm.[19] This is calculated as the percentage of value in a 4-digit NAICS industry code shipped from all of the plants belonging to the same firm to which the plant of interest belongs.

Other measures of market leadership include growth in market share from 1992 to 1997, the logged value of sales in 1997, and logged profits (value added minus salaries and wages) in 1997. To capture the underlying quality of the firm, I also calculate the relative total factor productivity of the establishment vis-à-vis others in the same primary product category, assigning a dummy variable equal to one if it is in the top 20% of its industry.

4.3 Controls

Another advantage of the Census data is the availability of rich controls for potentially confounding drivers of e-commerce adoption. Plant employment and age are readily available from the Census' Longitudinal Business Database (LBD). My empirical proxy for skill mix at the plant comes from the 1997 CMF and is calculated as the ratio of non-production workers wages to total salaries and wages. Census provides both a flag for plants belonging to multi-unit firms and a primary industry designation (at the 6-digit NAICS level). The comfortably large sample size permits extremely rich empirical specifications, including dummy variables for 86 4-digit NAICS industry classifications in most specifications.[20] Details and descriptive statistics for all variables are provided in Table 2; pair-wise correlations for key variables are presented in table 3.

5. Empirical Model

5.1 Bivariate Probit Model of Adoption

I employ a bivariate probit model of adoption to address the discrete nature of the adoption question and the possibility that the two choices are correlated (for instance by sharing hardware investments in servers and routers). Such a model assumes that a particular plant will adopt internet-based

[19] According to these arguments, larger firms have more internal resources to devote to innovation that might be difficult to acquire in the market. The focus is generally on the need for capital to devote to R&D and the role that large firm size may play in overcoming capital market imperfections, though the logical extension to other firm resources that might more directly influence co-inventive activity, is not difficult to imagine. For a review of the large literature on firm size and R&D see Cohen and Levin (1989). For a treatment of how internal firm resources substitute for market resources in the adoption of information technology, see Forman, et al. (2008).

[20] All core results are also robust to the inclusion of NAICS6 dummies.

buying (B) or selling (S) if the net benefits (*NB*) of doing so are greater than 0. Thus, the probability of plant *i* adopting electronic practice *j* where $j \in \{B, S\}$ is captured by:

$$\Pr(a_{iB} = 1) = \Pr\left(NB(MS_i, X_i) + \varepsilon_{iB}) > 0\right) \text{ and}$$

$$\Pr(a_{iS} = 1) = \Pr\left(NB(MS_i, X_i) + \varepsilon_{iS}) > 0\right)$$

where net benefits are expressed as a function of market share (MS_i), a vector of other establishment, firm, and industry characteristics that influence e-commerce adoption (X_i), as well as an unobserved error term that can be different for each technology (ε_{ij}). Because establishments have the same observable characteristics for each equation, it is reasonable to worry that the unobservable characteristics might be also be correlated across the two technologies (i.e., $corr(\varepsilon_{iE}, \varepsilon_{iS}) \neq 0$). Bivariate probit estimation has the desirable property of allowing for flexible correlation patterns between the error terms and explicitly testing whether they are correlated in the data.[21]

This treatment looks at whether or not adoption has taken place by a particular date (in this case, the time of the Census survey), and does not model the change in adoption status over time. The implicit behavioral assumption of such probit models of adoption (David 1969) is that establishments with higher net benefits of adopting will adopt first, that the costs of adopting will tend to decline over time (as technology becomes less expensive) and that non-adoption in the cross section captures relatively lower net benefit from adopting the technology.

5.2 Identification

Identification in this model requires that market share and other explanatory variables not be simultaneously determined with adoption.[22] To mitigate this common econometric problem, I use lagged values of all explanatory variables – to 1997 – to help reduce simultaneity. Moreover, I include a rich set of controls for possible drivers of IT adoption that might confound the empirical results if not explicitly accounted for in the specification. For example, prior research finds strong correlations between IT adoption and other observable factors such as number of employees (e.g., Astebro 2002), age (Rogers 1995), and complementary skilled labor (Bresnahan et al. 2002). In addition, establishments belonging to

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[21] Specifically, if $\begin{bmatrix} \varepsilon_{iE} \\ \varepsilon_{iS} \end{bmatrix} \sim \text{Bivariate Normal}\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \sigma^2 \begin{pmatrix} \mathrm{I} & \rho\mathrm{I} \\ \rho\mathrm{I} & \mathrm{I} \end{pmatrix}\right)$, it estimates a coefficient for ρ.

[22] Failure to address this issue has plagued much of the empirical work in this area to date (Gilbert 2006; Blundell et al. 1999).

multi-unit firms may have access to additional resources that influence the investment decision (Forman et al. 2008), so I include an indicator of multi-unit status. To address the possibility that decisions for establishments within the same firm may be correlated, all standard errors are clustered at the firm level. Unobserved influence on the adoption decision driven by industry characteristics is addressed by a rich set of industry controls.

6. Results

6.1 Increasing Dominance in E-buying; Decreasing Dominance in E-selling

Tables 4-6 report the average marginal effects of the main bivariate probit analyses. They reveal a robust positive correlation between market leadership and e-buying, with an equally robust negative correlation between leadership and e-selling, supporting both of the main hypotheses. The appropriateness of the bivariate probit model is supported by a consistently significant coefficient on ρ , which captures the degree of correlation between the technology-plant-specific error terms.

According to the empirical results, incumbents with greater market share are far more likely than smaller plants to purchase indirect goods and services over the internet. All else equal, an increase in a plant's share of the product market by one standard deviation is associated with a 3-6 percentage-point increase in the likelihood of adoption from the average rate of 21% (see table 4). At the mean, this represents an 18-27% increase in the likelihood of internet-based buying.

The top panel of figure 2 illustrates how greatly the effect reported in column 2a of table 4 varies over a range of market share values.[23] The graph depicts a monotonic increase in the effect of market leadership as market share increases, from a low of just over one percentage point (or a 7% increase) to a high of over 9 percentage points (a 43% increase). Thus, the "market leader effect" is particularly strong for firms with the highest market shares, with some of the highest-output establishments being more than two times more likely to adopt e-buying than those with some of the lowest relative outputs.

The specifications reported in columns 3a and 5a of table 4 employ a firm-level definition of market leadership. The results are similar to those at the plant-level, though of somewhat smaller magnitude (especially once plant employment is taken into account).

Table 5 explores whether different measures of market leadership change the relationship between incremental process innovation and a dominant market position. Columns 1a and 2a indicate that higher levels of market share *growth* are not a significant factor in e-buying adoption. A one standard-deviation increase in the growth of plant market share only increases the e-buying probability by 1%; the

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[23] The precise range of the variable is not approved for disclosure by the Census Bureau, as they represent values for individual establishments in the sample.

firm-level variable is not statistically different from zero. Column 3a reports that a one-standard deviation in logged plant sales is associated with a 23% increase in the likelihood of e-buying, on par with the market share results. Profitability also has a positive, though somewhat smaller effect, in the neighborhood of 10% for a commensurate perturbation of the explanatory variable.

Almost none of these relationships hold in the case of e-selling adoption. As described in section 3, e-selling was a fundamentally different process innovation than e-buying and as such presented very different economic and organizational challenges to potential adopters. Results presented in table 4 indicate that a one-standard-deviation increase in a plant's market share is associated with a 2.2-3.5 percentage point decrease in the likelihood of e-selling. At the mean adoption of 14.6%, this represents a 16-24% decrease in probability. A similar effect is seen for the market share of the plant's parent firm.

The lower panel of figure 2 shows the distribution of marginal effects across the surface of logged market share for the e-selling part of the specification in column 2b of table 4. The striking feature of this graph is that, as market share of the establishment increases, the negative impact of market share on e-selling diminishes. This makes sense if economies of scale start to overcome the higher adjustment costs for the largest firms, increasing the net benefits they enjoy compared to smaller adopters. An inescapable possibility, however, is that large market share is statistically capturing monopoly power, and that either reduced competitive pressure or greater supply chain clout is serving to reduce the adjustment costs and risks associated with e-selling adoption. With this in mind, I address competitive effects in section 6.3.

Other measures related to market leadership evince a similarly negative correlation with the likelihood of e-selling. Table 5 reveals that growth in market share, logged sales and logged profits all have statistically significant negative coefficients and that the magnitudes for sales and profits are considerable – a 20% and 38% drop, respectively, for a standard deviation increase in these latter variables.

6.2 Omitted IT Capabilities

A central concern for estimating incumbent reactions to new technology is controlling for difficult-to-observe organizational characteristics whose omission would severely bias the results (Henderson 1993). In the particular case of IT-based process innovations, we can think about implementations of other information technology as investments in an organization's ability to standardize business processes, digitize them, and successfully fold the automation into existing routines and practices. Prior research in information systems refers to this as "lowering the knowledge barrier" for IT adoption (Attewell 1992, Fichman and Kemerer 1997). A robust correlation between firm size and IT adoption across a wide range of settings (Forman and Goldfarb 2006) suggests that larger firms are more likely to have the complementary organizational resources needed to succeed with incremental IT-based process innovation.

Thus, one worries that the e-buying results in tables 4 and 5 could merely be picking up this omitted organizational resource. A promising proxy for prior IT investments and related IT capabilities is Enterprise Resource Planning (ERP) applications, which are notoriously difficult to implement in terms of standardizing a wide range of complex business practices and whose presence would tend to boost the return to e-commerce adoption (AMR 1999b).

On the e-selling side, we need to worry about the confounding effects of EDI. If larger firms happen to be more likely to have legacy EDI systems (for instance due to economies of scale in adoption), and EDI substitutes for internet-based B2B transactions, a negative coefficient on size could be spuriously generated by this relationship.

Table 6 reports the coefficients on dummy variables indicating whether the establishment reports having fully-integrated ERP or an EDI network in place in 1999. These are not ubiquitous technologies in 1999: only 15% of establishments report having ERP and roughly 14% have EDI. However, the impact of these other IT investments on e-buying adoption is significant. The presence of an ERP "backbone" at the establishment boosts the likelihood of e-buying adoption by up to 4.9 percentage points, or nearly 23% (column 1a). EDI has a similar positive effect, suggesting that little indirect procurement is taking place over legacy EDI systems (likewise implying low or no switching costs).

The negative impact of EDI on e-selling, however, is striking – suggesting that EDI-based selling represents a viable substitute with non-trivial switching costs for these B2B transactions. Column 2b of table 6 reports a greater than 5-point drop in the e-selling probability, representing a 38% reduction. The impact of ERP is a bit ambiguous, with column 3b suggesting that it might have a marginally positive impact (a 7% positive correlation at the 11% significance level).

Another potentially troubling source of bias would be IT-related capabilities that are not embodied in prior (observable) IT investments. To address this, I estimate total factor productivity at the plant which should capture unobserved technology or managerial skill that may contribute to plant success while also influencing the e-business investment decision. The results in table 6 suggest that plants in the top productivity quintile[24] are somewhat (1.3 percentage points, or 6%) more likely to adopt e-buying; however, the relationship between productivity and e-selling is quite noisy.

However, the key take-away from Table 6 is that, even controlling for these other significant IT investments (which separately and together have very large effects on the likelihood of both e-buying and e-selling), the coefficients on market share *remain unchanged*. Thus we have to look elsewhere for an alternative explanation for the puzzling relationship between market leadership and e-selling adoption.

[24] Results are nearly identical if the top category includes the top two quintiles.

6.3 Unobserved Competitive Effects

An alternative framework that predicts a negative correlation between process innovation and market leadership comes from the "replacement effects" hypothesized in Arrow's (1962) seminal work. In this model, because market leaders enjoy higher rents from each unit of sales, they face a higher opportunity cost of innovating than firms that do not have this existing revenue stream. Protection from competition is generally assumed necessary for this result to hold in a dynamic setting (Gilbert and Newbery 1982).

It is conceivable, given the inter-industry heterogeneity in adoption reported in table 7 that large potential adopters of e-selling happen to be in markets with barriers to entry and less competition, which would allow for these replacement effects to show up in the data. To test for this possibility, I follow Aghion et al. (2005), in creating an approximate Lerner index to capture the intensity of competition.[25]

The Lerner index is ideally 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 sales and production costs (materials and wages) by total sales: $\frac{\text{(sales- cost of materials-wages)}}{\text{sales}}$. 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. Industry for this purpose is defined as a 4-digit SIC code.[26]

The results in table 7, however, report no evidence that variation in competitive pressure is correlated with variation in the market share coefficient. Some of this "non-result" may be attributable to the statistical identification challenges posed by trying to estimate the effect of product market competition while controlling for industry fixed effects. Note that the direct coefficient on the Lerner index is not significantly different from zero in column 1a. When industry dummies are removed from the model (see column 3a), the coefficient becomes significant (and, somewhat surprisingly, negative[27]), but the market-share coefficient loses its precision. Moreover, a similar lack of variation is found when a traditional Herfindahl index or 4-firm concentration ratio are used instead (results not shown). Thus, it is difficult to believe that unobserved competitive effects could be driving the observed decreasing dominance effect.[28]

[25] While concentration ratios or a Herfindahl index are more commonly used in empirical work, they have the disadvantage of being correlated *by definition* with market share.

[26] Census shifted from the SIC classification to NAICS for the first time in 1997

[27] This is contrary to prior empirical findings of a positive correlation between product market competition and innovation (e.g., Geroski 1995, Blundell et al. 1999).

[28] Separately, it may be interesting to note that variation in competitive pressure also does not seem to affect the robust increasing dominance results in e-buying.

6.4 Robustness Checks

The point estimates for both e-buying and e-selling are relatively stable across a broad range of specifications (see table 8), giving confidence in the robustness of these findings. The central relationships discussed thus far are visible without the controls, however, at least for e-buying, the controls are necessary to separately identify the economies of scale in output and the economies of scale in the number of employees (column 2) Also, while the paper is focused on the *internet*-based e-buying and e-selling the results look very similar when the analysis is run for e-buying or e-selling over any network platform column 3).

The results are *not* robust to certain definitions of the dependent variable. In particular, a naïve probit regression of market share on "e-commerce" (table 8 column 4), where the dependent variable is defined as either e-buying or e-selling (or both) over the internet, shows no statistically significant relationship between the logged market share of the plant and adoption. The coefficient on the firm level variable is negative and significant (not shown). The robust increasing dominance result for the straightforward, less strategically sensitive process would have been completely obscured without a careful treatment of the underlying heterogeneity.

Table 9 reinforces the generalizability of these results by presenting the results of individual industry-level regressions. Each industry is defined at the 3-digit NAICS code level for ease of reporting.[29] In addition to displaying the wide variation in adoption of e-buying and e-selling across industries, the table reports the average marginal effect of the market share coefficient for each e-business process and each industry. While one observes a certain amount of variation amongst industries in magnitudes of the results, the general pattern of increasing dominance in e-buying and decreasing dominance in e-selling holds rather broadly.

6.5 Complexity

Thus far, the results are consistent with the argument that e-selling constituted a radical innovation with disproportionate adjustment costs for leaders, and that those costs arose from a combination of strategic sensitivity and complexity of the underlying business processes affected by the technological change. Obvious alternative explanations have so far been unsupported by the empirical evidence.

Additional support for the role of complexity in driving the observed behavior comes from the coefficient on the multi-unit flag. Firms that span multiple establishments typically engage in more distinct business processes (McElheran and Riggs 2010) and as a result ought to face higher business

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29 Similar results were found at the 4-digit level, sometimes with increased precision, but are not reported due to space constraints and limits imposed by the Census Bureau's disclosure policies.

process complexity and higher internal coordination costs (in the Coasian sense). Thus, if e-selling entails coordination costs related to automating or switching the network platform for complex and strategically important business activities, we would expect these costs to be disproportionately higher not only for larger firms, but for multiple-establishment firms, as well. This is precisely the pattern of results seen in table 4: belonging to a firm consisting of more than one plant reduces the likelihood of e-selling adoption by 2.3 to 3.7 percentage points, representing a significant 16-25% decrease in the e-selling probability. A similar result can be seen on the coefficient for the number of sites at the firm (not cleared for disclosure).

The pair-wise correlation between multi-unit status and market share is both significant and large (.479 – see table 3), so including it in the regression diminishes the coefficient on market share – but only moderately, indicating that it is picking up a related but not entirely overlapping effect. Splitting the sample by multi-establishment status (results not shown) reveals that leaders are still significantly less likely to adopt e-selling, even among single-establishment firms. Overall, this pattern of results is consistent with adjustment costs for this type of innovation that increase with the complexity of a business process – regardless of whether that complexity arises from greater scale of output or from organizational structure.

7. How to Identify "Radical" Business Process Innovations

An interesting question related to the e-selling results is whether all of the salient coordination and adjustment costs are internal to the firm. Another pattern of results is consistent with the proposition in section 2 that part of the story lies in the fact that e-selling is not only strategically sensitive and complex, but *also* must span the firm boundary.

Because the Census CNUS survey queries firms on a wide range of information technology uses, it is possible to observe incumbents' adoption of many other types of information technology and IT-based practices. I conduct probit analyses of adoption on many of these to see if variation amongst them helps advance our understanding of how to identify and define radical innovation in the business process setting. Two of these technologies are highly complex IT solutions that touch on strategically sensitive business processes: ERP and EDI. I also look at adoption of IT uses that span the firm boundary. However, most of these are either less complex (e.g., electronic catalogs) or else are arguably less related to a firm's core competitive advantage (e.g., sharing designs, order status, and logistics information with existing customers). Unfortunately, no other e-business process covered by the survey possessed the same level of complexity, strategic sensitivity, and boundary spanning that e-selling did, except possibly EDI.

Table 10 reports the results for the various analyses. The first column lists the e-business process of interest, with the lower panel listing the different types of information that are shared with customers over networked computers (i.e., they are all boundary-spanning processes). They are listed in descending order of adoption, which is reported in column 2. The third presents average marginal effects of the market share coefficient from probit regressions with the same covariates as those presented in Table 4, columns 4a and 4b – only with different dependent variables, depending on the e-business process in question.

The striking feature of this table is that market share is positively and significantly related to most of them, including the most complex and (ERP) and the majority of boundary-spanning activities. The exceptions lie with EDI and at the bottom of the table (sharing demand forecasting, production scheduling, and inventory data), where the market share effect is not statistically different from zero. These latter results could be an artifact of the low level of adoption, but could also relate to the fact that sharing these types of dynamic internal production data with customers is both relatively more complicated and more strategically sensitive than the other customer-focused processes. This would bring these particular activities closer to what is involved in e-selling adoption – and make them, therefore, more radical.

EDI is a somewhat different story, because it possessed additional features that make its "radicalness" under this particular definition particularly difficult to evaluate. A defining characteristic of EDI implementation is the enormous fixed investment required to set up its proprietary network structure. Keeping in mind results from figure 2 suggesting that economies of scale in adoption mitigated the otherwise negative correlation with market share, it is plausible that EDI posed the same types of challenges to market leaders that e-selling did – but that the need for scale in adoption overwhelmed this effect in the statistical results.

A formal test of this working definition of what makes a business process innovation radical would require in-depth analysis of the salient details of *all* of these processes (and potentially more) – and thus lies beyond the scope of this paper. It is left to future work to flesh out a comprehensive taxonomy of business process innovations and test how market leaders respond to the vast array of interesting and important advances enabled by modern information technologies.

8. Conclusion

The purpose of this paper has been to shed light on whether, when, and why market leaders might be more likely to adopt new innovations, and to do so in the novel setting of IT-enabled business processes. Strong evidence of increasing dominance is found in the case of e-buying: an increase in a plant's share of the product market by one standard deviation is associated with an 18-27% increase in the likelihood of internet-based indirect purchasing. Similar results hold for alternative definitions of market leadership. For this straightforward, strategically peripheral firm activity, it appears that external market factors and internal characteristics reinforce each other to make adoption relatively more beneficial and/or easier for the largest, most successful firms. This is consistent with the hypothesis that market leaders will be more likely to adopt incremental business process innovations.

This is clearly not the case for e-selling, for which a standard-deviation increase in plant market share is associated with a 16-24% *decrease* in the probability of adoption. For this far more complex, strategically sensitive activity, market leaders faced disproportionate risks and adjustment costs, making adoption less attractive for firms with the largest market shares. This is consistent with the complementary hypothesis that market leaders will be less likely to adopt business process innovations that are radical.

The first contribution of the paper, therefore, is robust, multi-industry evidence that market leaders *are* more likely to adopt certain types of innovations. Unlike prior work that has been plagued by shortcomings in both econometric techniques and sample definitions, my results leverage a large, representative data set that allows me to not only control for underlying industry heterogeneity, but also report industry-by-industry results to document the prevalence of this behavior.

Moreover, it documents the behavior in an understudied but increasingly important realm of firm activity: business process innovation. The vast majority of prior innovation research has focused on product innovation. This ignores the costly and important developments that take place "inside the black box" (Rosenberg, 1982) of the firm to boost productivity and competitiveness. In particular, it overlooks the tremendous potential of new networked technology such as the internet to jump-start innovation throughout the economy (Brynjolfsson and Saunders 2010). Understanding the competitive implications of these new technologies is a growing imperative in the wired economy.

Simultaneously comparing the adoption of two different types of innovations yields useful insights into *when* leaders have an advantage in business process innovation – and when they do not. Extending existing theories about radical and incremental innovation into the business process context yields the novel insight that many of our product-based intuitions transfer well to the business process setting: market leaders are far more likely to adopt incremental business process innovations, while radical changes may encounter resistance amongst the most successful firms. While this distinction of *when* leaders will embrace new innovations (or not), makes a great deal of intuitive sense, this study represents the first multi-industry evidence that this is an empirically – as well as theoretically – useful way to understand and predict firm behavior.

This paper also sheds some light on the mechanisms driving this behavior – i.e., the *why*. In order to apply the incremental/radical distinction to the e-business setting, I develop a framework for identifying when a given business process innovation is likely to fall into which category. The qualitative differences between e-buying and e-selling are consistent with a distinction based on whether the process was strategically sensitive (and therefore risky to change) and/or relatively complex (and therefore costly to change). The third criterion proposed for defining a business process as radical is whether or not it spans the firm boundary. The additional coordination and co-invention costs involved in changing and standardizing core business processes with stakeholders outside the firm hierarchy – and who may not all share the same interests and needs – is a central concern.

Leveraging the rich Census survey, I test the robustness of this three-fold definition by comparing market share effects across a wide range of e-business processes with different characteristics. Interestingly, I find that market leaders have a greater propensity to adopt almost all of the other processes, including the most complex and strategically sensitive ones such as adopting enterprise resource planning (ERP) systems. A key difference between ERP adoption and e-selling adoption, however, is the need to coordinate business processes with customers, i.e., across the firm boundary. Yet leaders also are more likely to adopt most of the boundary-spanning innovations, suggesting this to be a necessary but not sufficient condition for "radicalness." Thus, I conclude that the *combination* of complexity, strategic sensitivity and boundary-spanning is what creates the particular challenge observed for market leaders in the case of e-selling and potentially other business process innovations.

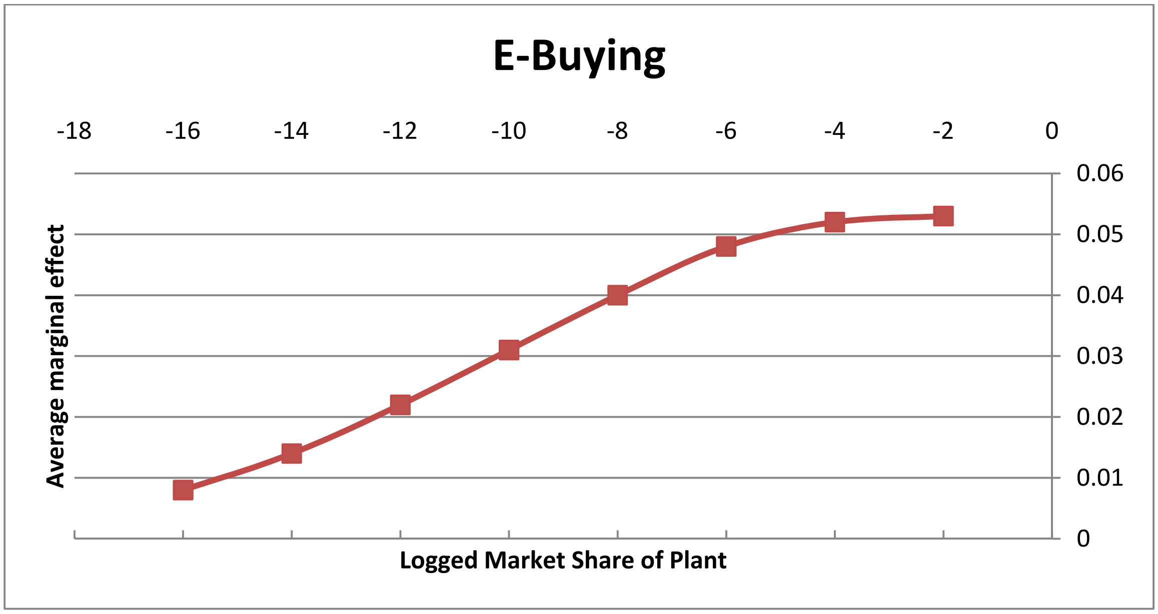
The development of such a classification framework has important practical implications. Being able to apply what we know about the innovative behavior of firms requires the means to distinguish, *ex ante*, whether a proposed change lies on the incremental or radical end of the spectrum. While far more work – both empirical and theoretical—is needed to place different types of innovations in a comprehensive taxonomy, my analysis of what made e-selling radical is a step in this direction. My results indicate that, in cases where firms must coordinate complex and strategically important activities throughout a larger organization, across more establishments, while spanning the firm boundary, adoption will tend to take place primarily among smaller firms. This inter-firm coordination challenge is an important strategic consideration as businesses grow ever more dependent on the performance of their extended value chain for success. Lagging firms may discover new opportunities to leapfrog their larger competitors using certain business-to-business process innovations and IT-enabled supply chain relationships.

While the context of this paper makes it relevant to a burgeoning literature on firm adoption of information and communication technologies (for a useful review, see Forman and Goldfarb 2006), the distinction between straightforward IT adoption and process innovation enabled by new information technology is worth emphasizing. The potential of the internet to transform internal firm processes was much-hyped but under-utilized in the late 1990s. Diffusion of internet-based e-buying was only at 21% of plants, and even less – 15% – for e-selling. Uncertainty about the potential of this information technology to confer any kind of competitive advantage was high, and the investment in adapting the technology to existing business processes (or vice versa) typically dwarfed the expenditure on software licenses. This co-invention of information technology and business processes constitutes an important but difficult to observe (and hence understudied) innovative activity. As such, this setting offers a complementary view to studies that focus on R&D expenditure and patents as measures of innovation.

Important drawbacks of the empirical settings, however, must be kept in mind. While being both rich and expansive in terms of the number of observations and industry variation, it is limited to a single year of data. This prevents an interesting exploration into the precise timing of investment decisions and whether the leadership effects (both positive and negative) persist throughout the diffusion of the new technologies. The CNUS survey observes manufacturing establishments during an early stage of internet diffusion among firms – and leaves open the question how incumbent behavior might evolve in later periods. The single year also prevents desirable estimation strategies such as differencing out unobserved firm-fixed effects that could be correlated with both large market share and e-business adoption. Investigating and exploiting temporal changes in this type of innovative behavior would be a useful direction for future research.

Much additional work remains to be done. The ultimate justification for studying whether market leaders are more likely to adopt new innovations is that this innovative activity may provide competitive advantages that reinforce existing firm strengths – creating a reinforcing cycle of increasing dominance. Conversely, market leaders who resist adopting important radical new technologies may find themselves replaced at the top of the market share distribution. An important question, therefore, is what the long-term competitive implications are of adopting e-buying, e-selling, or other frontier business process innovations. Which types of business process innovations turn out to be the most advantageous (or not)? Does this vary by industry? How do these effects compare to more "traditional" innovations in production processes or product offerings? The findings presented here cannot speak to these types of long-term strategic implications, yet they offer a springboard for future research that may deepen our understanding of the role that different types of innovation play in competitive strategy and market outcomes in a wide range of industry settings.

Figure 2. Market Share Effects across the Variable Surface



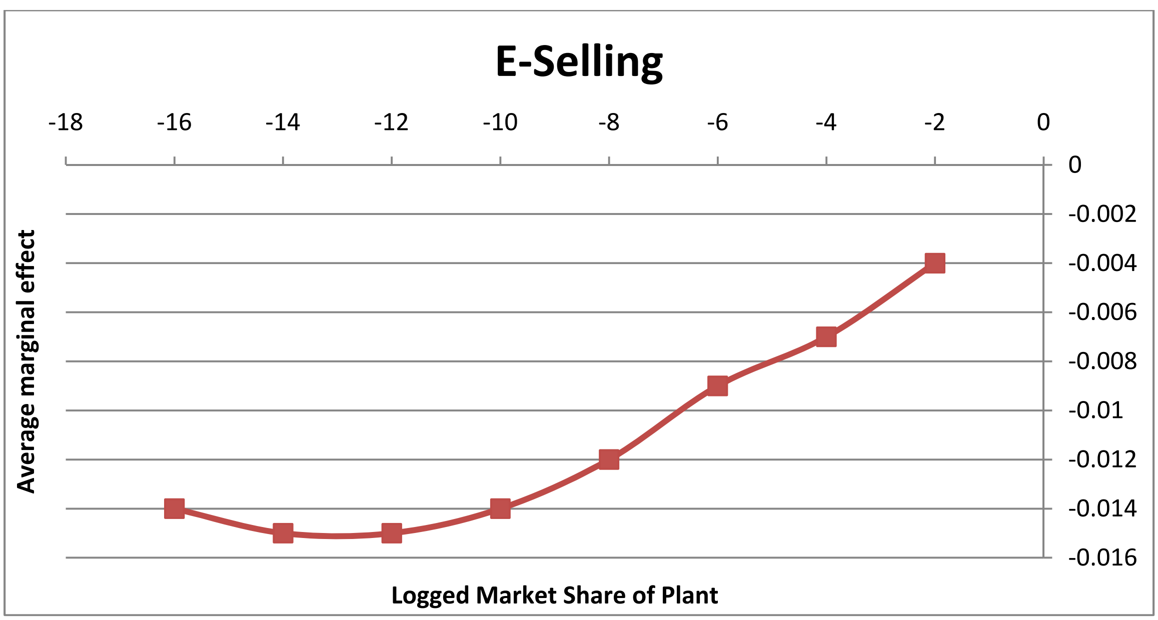


Table 2. Definitions, Means, and Standard Deviations of Variables

Variable	Definition/Variable Name	Estimated Population Mean†	Estimated population Std. Dev.
E-BUY	= 1 if the plant reports buying over the internet; 0 else.	.213 (.004)	.410
E-SELL	= 1 if the plant reports selling over the internet; 0 else	.146 (.004)	.353
PLANT_ MKTSHARE	Plant share of NAICS4 product market sales in the United States	.0004 (7.34×10^{-6})	.002
LN_PLANT_ MKTSHARE	$\ln\left(\frac{sales_{\text{plant}}}{\sum_{\text{all plants in NAICS4}} sales_{\text{plant in NAICS4}}}\right)$ in 1997	-9.53 (.019)	1.75
FIRM_ MKTSHARE	Share of NAICS4 sales in the United States attributed to the plant's parent firm	.003 (.00005)	.015
LN_FIRM_ MKTSHARE	$\ln\left(\frac{\sum_{\text{all plants in firm}} sales_{\text{plant in NAICS4}}}{\sum_{\text{all plants in NAICS4}} sales_{\text{plant in NAICS4}}}\right)$ in 1997	-9.06 (.023)	2.32
MKTSHARE_GROWTH	Change in plant share of SIC4 product market from 1992 to 1997	.0001 (.00002)	.005
EMP	Total employees at the plant in 1997	85 (1.04)	271
LN_EMP	Log of total employees at the plant in 1997	3.51 (.012)	1.22
LN_PROFIT	Log of value-added minus salaries and wages in 1997	6.93 (.019)	1.74
LN_SALES	Log of plant total revenues in 1997	8.20 (.017)	1.60
AGE<10	=1 if the establishment is 10 or fewer years old; 0 else	.287 (.005)	.453
MULTI-UNIT	=1 if plant is owned by a multiple-unit (i.e., multi-plant) firm	.328 (.004)	.469
SKILLMIX	Share of non-production worker wages to total salaries and wages in 1997	.375 (.002)	.185
EDI	=1 if plant has Electronic Data Interchange technology	.139 (.003)	.355
ERP	=1 if plant has a fully-integrated Enterprise Resource Planning application	.152 (.003)	.359
LERNER	1 minus the profit-to-sales ratio		

†Standard errors in parentheses.

Table 3. Variable Correlations

	Plant MS	Firm MS	Logged Employees	Multi-Unit	Skill Mix	Age<10	Logged Sales	Logged Profit	Top 20% TFP	Lerner
Plant Market Share	1									
Firm Market Share	.804	1								
Logged Employees	.738	.584	1							
Multi-Unit Flag	.479	.657	.423	1						
Skill Mix	-.149	-.233	-.141	-.195	1					
Age<10	-.073	-.057	-.105	-.041	-.009	1				
Logged Sales	.853	.747	.845	.543	-.115	-.085	1			
Logged Profit	.776	.668	.769	.492	-.103	-.076	.910	1		
Top 20% TFP	.076	.082	-.053	.068	-.065	.015	.078	.253	1	
Lerner	-.050	-.003	-.081	-.032	-.118	.014	-.068	-.192	-.011	1

Table 4. Bivariate Probit Estimates: Market Share Effects in E-Business Adoption

	(1a) E-Buy	(1b) E-Sell	(2a) E-Buy	(2b) E-Sell	(3a) E-Buy	(3b) E-Sell	(4a) E-Buy	(4b) E-Sell	(5a) E-Buy	(5b) E-Sell
LN_PLANT_ MKTSHARE	**.020*** (.002)**	**-.020*** (.002)**	**.033*** (.002)**	**-.013*** (.002)**			**.022*** (.005)**	**-.016*** (.004)**		
LN_FIRM_ MKTSHARE					**.021*** (.002)**	**-.012*** (.002)**			**.007*** (.002)**	**-.013*** (.002)**
LN_EMP							**.016** (.006)**	**.004 (.004)**	**.032*** (.004)**	**.0007 (.003)**
MULTI-UNIT			.006 (.008)	-.037*** (.006)	-.001 (.009)	-.023*** (.007)	.005 (.008)	-.037*** (.006)	.002 (.009)	-.023*** (.007)
AGE<10			.032*** (.008)	-.010* (.006)	.025*** (.008)	-.009 (.006)	.034*** (.008)	-.010* (.006)	.034*** (.008)	-.009 (.006)
SKILLMIX			.024 (.017)	.025** (.013)	.037** (.017)	.020 (.013)	.026 (.017)	.026** (.013)	.033* (.017)	.020 (.013)
Industry Controls (86 NAICS4 Dummies)	**No**		Yes		Yes		Yes		Yes	
ρ	.428 (.020)		.399 (.020)		.399 (.020)		.398 (.020)		.397 (.020)	
N	~35K		~35K		~35K		~35K		~35K	
Wald X^2	198.62		4989.98		9317.15		5677.89		7967.69	

Weighted maximum-likelihood bivariate probit estimation, reporting estimated average marginal effects for continuous variables and discrete change from 0 to 1 for dummy variables. Robust standard errors are clustered by firm and included in parentheses. Significance levels are denoted as follows: *10%, **5%, ***1%.

Table 5. Bivariate Probit Estimates: Other "Leadership" Effects in E-Business Adoption

	(1a) E-Buy	(1b) E-Sell	(2a) E-Buy	(2b) E-Sell	(3a) E-Buy	(3b) E-Sell	(4a) E-Buy	(4b) E-Sell	(5a) E-Buy	(5b) E-Sell
GROWTH_ MKTSHARE_ PLANT	**.546**** **(.232)**	**-.492**** **(.213)**								
GROWTH_ MKTSHARE_ FIRM			**-.002** **(.089)**	**-.155***** **(.062)**						
LN_SALES					**.030***** **(.005)**	**-.018***** **(.004)**				
LN_PROFIT							**.015***** **(.004)**	**-.008***** **(.003)**		
LNEMP	.040*** (.003)	-.011*** (.003)	.040*** (.003)	-.011*** (.003)	.008 (.006)	.006 (.005)	.023*** (.005)	-.004 (.004)	.041*** (.003)	-.014*** (.002)
MULTI-UNIT	.014* (.008)	-.045*** (.006)	.014* (.008)	-.045*** (.006)	.003 (.008)	-.037*** (.006)	.005 (.008)	-.036*** (.006)	.015* (.007)	-.042*** (.006)
AGE<10	.038*** (.011)	-.014* (.008)	.038*** (.011)	-.014* (.008)	.035*** (.008)	-.010* (.006)	.035*** (.008)	-.007 (.006)	.029*** (.008)	-.005 (.006)
SKILLMIX	.035** (.017)	.031*** (.013)	.035** (.017)	.031*** (.013)	.021 (.0017)	.028** (.013)	.028 (.018)	.024* (.013)	.038** (.017)	.019 (.013)
Industry Controls	Yes (SIC2)		Yes (SIC2)		Yes (NAICS4)		Yes (NAICS4)		Yes (NAICS4)	
ρ	.386 (.022)		.386 (.022)		.398 (.020)		.393 (.021)		.393 (.020)	
N	~30K		~30K		~35K		~33K		~35K	
Wald X^2	3485.28		8301.87		5692.59		5181.73		5764.67	
Degrees of Freedom	48		48		180		180		180	

Weighted maximum-likelihood bivariate probit estimation, reporting estimated average marginal effects for continuous variables and discrete change from 0 to 1 for dummy variables. Robust standard errors are clustered by firm and included in parentheses. Significance levels are denoted as follows: *10%, **5%, ***1%.

Table 6. Bivariate Probit Estimates
Effects of other Information Technology Investments & Controls for Total Factor Productivity

	(1a) E-Buy	(1b) E-Sell	(2a) E-Buy	(2b) E-Sell	(3a) E-Buy	(3b) E-Sell	(4a) E-Buy	(4a) E-Sell
LN_PLANT_ MKTSHARE	**.024*** (.005)**	**-.016*** (.004)**	**.021*** (.005)**	**-.015*** (.004)**	**.023*** (.005)**	**-.015*** (.004)**	.021*** (.005)	-.016*** (.004)
LN_EMP	.011** (.006)	.006 (.004)	.013** (.006)	.007* (.004)	.009 (.006)	.009** (.004)	.017*** (.006)	.004 (.004)
ERP	**.049*** (.007)**	.003 (.006)			**.045*** (.007)**	**.010† (.006)**		
EDI			**.047*** (.007)**	**-.055*** (.007)**	**.041*** (.008)**	**-.057*** (.007)**		
Top 20% TFP							**.005 (.006)**	**-.001 (.005)**
MULTI-UNIT	-.004 (.007)	-.033*** (.006)	.002 (.008)	-.033*** (.006)	-.006 (.007)	-.030*** (.012)	.005 (.008)	-.037*** (.006)
AGE<10	.029*** (.008)	-.008 (.006)	.034*** (.008)	-.009 (.006)	.029*** (.008)	-.008 (.006)	.034*** (.008)	-.010* (.006)
SKILLMIX	.013 (.016)	.031*** (.012)	.025 (.017)	.027** (.013)	.013 (.016)	.031*** (.012)	.028 (.017)	.025** (.013)
Industry Controls (86 NAICS4 Dummies)	Yes		Yes		Yes		Yes	
ρ	.404		.403		.409		.398 (.020)	
N	~32K		~35K		~32K		~35K	
Wald X^2	7662.33		3678.22		7671.27		5733.28	
Degrees of Freedom	182		182		184		182	

Weighted maximum-likelihood bivariate probit estimation, reporting estimated average marginal effects for continuous variables and discrete change from 0 to 1 for dummy variables. Robust standard errors are clustered by firm and are included in parentheses. Significance levels are denoted as follows: †11%, *10%, **5%, ***1%.

Table 7. Competition Effects

	Weighted Lerner index including industry controls				**Comparison model excluding Lerner**		**Weighted Lerner index (no industry controls)**	
	(1a) E-Buy	**Surface detail**	**(1b) E-Sell**	**Surface Detail**	**(2a) E-Buy**	**(2b) E-Sell**	**(3a) E-Buy**	**(3b) E-Sell**
LN_PLANT_ MKTSHARE (SIC4)	**.010*** (.003)**		**-.007*** (.002)**		.009** (.003)	-.006*** (.002)	.0007 (.003)	-.012*** (.002)
@ Lerner = 0		.009*** (.003)		-.009*** (.003)				
@ Lerner = .25		.009*** (.003)		-.008*** (.003)				
@ Lerner = .5		.010*** (.003)		-.007*** (.002)				
@ Lerner = .75		.010*** (.003)		-.006*** (.002)				
@ Lerner = 1		.010*** (.003)		-.006*** (.002)				
LERNER	.038 (.048)		-.055 (.033)				**-.082** (.039)**	**-.076** (.033)**
LN_EMP	.029*** (.004)		-.005* (.003)		.029*** (.004)	-.005* (.003)	.037*** (.004)	-.002 (.003)
MULTI-UNIT	.009 (.007)		-.041*** (.006)		.009 (.007)	-.042*** (.006)	.011 (.007)	-.046*** (.006)
AGE<10	.036*** (.008)		-.009 (.006)		.036*** (.008)	-.009 (.006)	.033*** (.008)	-.008 (.006)
SKILLMIX	.034** (.017)		.035*** (.012)		.034** (.017)	.035*** (.012)	.062** (.016)	.043*** (.012)
Industry Controls	SIC2				SIC2		No	
ρ	.398 (.021)				.398 (.021)		.424 (.024)	
N	~35K				~35K		~35K	
Wald X^2	4241.89				5810.71		520.05	
Degrees of Freedom	50				48		12	

Weighted maximum-likelihood bivariate probit estimation, reporting estimated average marginal effects for continuous variables and discrete change from 0 to 1 for dummy variables. Details of how market share effects vary across the surface of the appropriate Lerner index (defined at the NAICS4 industry level) are reported at the following values: 0, .25, .5, .75, and 1. These values are arbitrary and may not even represent actual values in the data. They are provided for illustrative purposes only. Robust standard errors are clustered by firm and are included in parentheses. Significance levels are denoted as follows: *10%, **5%, ***1%.

Table 8. Robustness Checks

	No NAICS4 (1)		Add Employees No NAICS4 (2)		ANY NETWORK PLATFORM (3)		E-Commerce (4)
	E-Buy (1a)	**E-Sell (1b)**	**E-Buy (2a)**	**E-Sell (2b)**	**E-Buy (3a)**	**E-Sell (3b)**	**Either (4)**
LN_PLANT_MKTSHARE	.018*** (.002)	-.016*** (.002)	-.003*** (.003)	-.017*** (.003)	.021*** (.004)	-.011** (.004)	.004 (.007)
LN_FIRM_MKTSHARE							
LN_EMP			.040*** (.004)	.002 (.003)	.004 (.005)	.027*** (.005)	.037*** (.008)
MULTI-UNIT	.025*** (.007)	-.043*** (.006)	.013* (.007)	-.044*** (.006)	.009 (.007)	-.008 (.007)	-.052*** (.011)
AGE	.025*** (.008)	-.010 (.006)	.033*** (.008)	-.010 (.006)	.031*** (.007)	-.015** (.007)	.027** (.012)
SKILLMIX	.068*** (.016)	.046*** (.012)	.068*** (.016)	.046*** (.012)	-.001 (.015)	.048*** (.015)	.094*** (.025)
Industry Controls (NAICS4 Dummies)	No		No		Yes		Yes
ρ	.428 (.020)		.423 (.020)		.376 (.017)		n/a
N	~35K		~35K		~35K		~35K
Wald X^2	365.91		502.13		2153.88		823.64
Degrees of Freedom	8		10		180		90

Weighted maximum-likelihood bivariate probit (columns 1-3) or probit (column 4) estimation, reporting estimated average marginal effects for continuous variables and discrete change from 0 to 1 for dummy variables. Robust standard errors are clustered by firm and are included in parentheses. Significance levels are denoted as follows: *10%, **5%, ***1%.

Table 9. Industry-Level Adoption and Market Leadership Coefficients

NAICS 3 Code	Industry	Approx N	% E-buy (estimated)	% E-Sell (estimated)	Average marginal effect of logged plant market share		Std. Dev.
					E-Buy	**E-Sell**	
311	Food	2,900	18.6%	8.3%	**.040*****	**-.012***	1.52
312	Tobacco & Bev.	400	22.8%	12.0%	.019	-.0007	1.91
313	Textile Mills	700	15.9%	11.1%	-.026	-.020	1.45
314	Textile Products	400	6.1%	16.4%	**.049*****	.002	1.42
315	Apparel	800	7.6%	6.6%	**.020*****	**.020****	1.89
316	Leather	200	17.4%	20.5%	.026	-.053	1.49
321	Wood	2,000	12.8%	7.7%	.002	**-.035*****	1.49
322	Paper	1,500	20.5%	11.9%	**.023****	-.004	1.84
323	Printing	2,000	32.0%	34.2%	-.007	-.006	1.28
324	Petroleum & Coal	500	16.1%	2.9%	Omitted due to disclosure restrictions		
325	Chemical	2,400	22.5%	12.0%	**.021***	**-.012**	1.59
326	Plastics & Rubber	2,300	25.0%	13.6%	-.022	-.008	1.39
327	Non-Metallic Mineral	2,000	12.0%	5.6%	**.031*****	.006	1.53
331	Primary Metal	1,100	24.6%	10.1%	**.033****	-.010	1.56
332	Forging & Stamping	5,300	18.7%	13.1%	.009	-.005	1.51
333	Machinery	3,500	25.3%	16.5%	**.026****	**-.025****	1.50
334	Computers & Electronics	1,700	37.9%	21.1%	-.001	-.007	1.63
335	Elec. Appliances, Components	1,000	27.2%	13.9%	.0007	-.006	1.44
336	Transportation	1,600	25.7%	12.4%	-.006	-.013	1.82
337	Furniture	1,200	16.2%	8.5%	-.022	**.021****	1.48
339	Misc.	1,500	24.1%	18.5%	**.041***	-.028	1.42

Record counts, e-buying and e-selling adoption, and market share coefficients and standard deviations reported at the industry (NAICS3) level. Average marginal effects of the coefficient on logged plant market share acquired using weighted maximum-likelihood bivariate probit estimation. All specifications include controls for belonging to a multi-establishment firm, skill mix of its employees, and whether or not the establishment is 10 or fewer years old. Robust standard errors are clustered by firm and included in parentheses. Significance levels are denoted as follows: *10%, **5%, ***1%.

Table 10. Adoption and Leadership Effects for other Electronic Business Processes

E-BUSINESS PRACTICE	**%** ADOPTION (estimated for population)	LN_PLANT MARKETSHARE COEFFICIENT
"E-COMMERCE" (either internet-based e-buying or e-selling – or both)	29.3%	.004 (.007)
ERP	15.2%	.023*** (.005)
EDI	13.9%	.020*** (.005)
Plant uses networked computers to share the following information with customers:		
DESIGN	11.2%	.015*** (.005)
CATALOG	9.2%	.014*** (.004)
LOGISTICS	4.4%	.012*** (.003)
ORDER STATUS	4.3%	.008*** (.003)
DEMAND FORECAST	3.5%	.002 (.003)
PRODUCTION SCHEDULING	2.4%	.003 (.003)
INVENTORY DATA	2.3%	.002 (.002)

Estimated adoption rates and average marginal effects of logged plant market share reported by e-business process. Market share effects acquired via weighted maximum-likelihood probit estimation of regressions using a 0-1 measure of adoption of each process as the dependent variable, with additional controls for logged employees at the plant, belonging to a multi-establishment firm, skill mix, and age, as well as 86 NAICS4 industry dummies. Robust standard errors are clustered by firm and are included in parentheses. Significance levels are denoted as follows: *10%, **5%, ***1%.

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