THE EXTROVERTED FIRM: HOW EXTERNAL INFORMATION PRACTICES AFFECT PRODUCTIVITY

Prasanna B. Tambe
Stern School of Business, New York University
New York, NY 10012
tambe@stern.nyu.edu

Lorin M. Hitt
The Wharton School, University of Pennsylvania
Philadelphia, PA 19104
lhitt@wharton.upenn.edu

Erik Brynjolfsson
MIT, Sloan School of Management
Cambridge, MA 02139
erikb@mit.edu

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Abstract

We combine detailed survey data on firms' organizational practices with information technology (IT) intensity measures to test the hypothesis that along with decentralization, external focus is an important determinant of returns to IT investments. Using survey-based measures, we first show that external focus, decentralization, and information technology investments are highly correlated and associated with a firm's product innovation capabilities. We then report estimates from a complementarities model that indicates that the output elasticity of IT investment is about 8-9% for firms that are both decentralized and externally focused, while IT investments in firms that have one or neither of these organizational assets in place do not significantly increase productivity. Both our product development and productivity estimates are robust to IV regressions that address the potential endogeneity of organizational investments. Our results may help explain why more "networked" regions and economies have experienced especially high returns to IT investment.

Keywords: Information Technology, Productivity, Organizational Practices, External Focus, Complementarities, High Performance Work Practices, Product Development, High-Tech Clusters

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Introduction

This study investigates the role of an organization's "external focus", defined as the practices it implements to capture information from its external environment, on generating productivity from its information technology (IT) investments. Our focus on the organizational determinants of IT productivity is closely related to a literature that focuses on the operational drivers of IT value (Melville, Kraemer, & Gurbaxani, 2004), as well as to a literature on the importance of new organization and workplace practices to the recent productivity gains experienced by firms in the US economy (Black & Lynch, 2005). A leading explanation for the high variance in returns to computerization observed in firm-level data is that some firms, through luck or skill, have the right endowment of organizational structures, processes, and skills to reap superior benefits from new technologies. For example, researchers have used organizational micro-data to demonstrate that information technologies are associated with higher productivity in firms characterized by decentralized architectures, higher levels of human capital, and team-based production (Bresnahan, Brynjolfsson, & Hitt, 2002; Caroli & Van Reenen, 2002). This system of technological and organizational innovations has been linked to productivity improvements through greater product customization and increased product variety (Bartel, Ichniowski & Shaw, 2008).

Although prior empirical research on organizational complements to IT investment has primarily focused on the importance of *internal* workplace factors such as decentralization, firm size, or firm culture, modern perspectives on the innovative process emphasize the importance of a network of *external* information relationships (Powell, Koput, and Doerr, 1996; Bradley and Nolan, 1998). For example, innovative firms often obtain information on new products and technologies from customers, suppliers, partners, or new employees. Indeed, research on "information-age" organizations has demonstrated that a combination of decentralized architectures and external information awareness characterize many modern firms competing in industries that are characterized by rapid product cycles (Mendelson, 2000), and the importance of information technologies for managing information flows has had a prominent role in the recent literature on effective product development processes in uncertain

environments. Therefore, we expect that a firm's ability to promote cross-boundary information flows is a key determinant of the benefits it can derive from investing in information technologies.

Because of the difficulty in measuring organizational assets within firms, however, there has been little research focused on identification of any organizational complements beyond decentralization. This paper uses primary survey data to test the hypothesis that in addition to decentralization, external information practices are an important complement to IT investments in modern firms. We argue that information technologies are most productive in decentralized organizations *because* they allow firms to respond more quickly and effectively to external stimuli, and that one of the central mechanisms through which this system of complements is associated with greater productivity is through product innovation. The implication is that organizations that do not have the appropriate mechanisms in place through which to capture environmental information will not experience the same productivity gains from IT investments, even if they have taken steps to decentralize their internal information processes. Therefore, some of the variance in IT returns observed in the literature on IT productivity may be explained by differences in decentralization as well as by practices designed to capture external information flows.

Empirical identification and measurement of these "hidden" organizational assets is important for several reasons. Although a robust link between IT expenditures and productivity has been established in the academic literature, there continues to be significant interest in understanding why some firms derive greater benefits from IT investments than others. A leading hypothesis is that the excess returns observed in these firms result from the unobservability of complementary organizational assets (Brynjolfsson & Hitt, 2000; Dedrick, Gurbaxani, & Kraemer, 2003). Identifying these organizational complements, therefore, has implications for the management of a firm's IT resources. Beyond defining organizational best practices regarding IT infrastructure, however, potential complementarities between IT investment and external focus may also have implications for other managerial choices, such as where firms locate. For example, scholars have argued that some regions, such as the Silicon Valley, are characterized by a much more open flow of information among firms (Bresnahan & Gambardella, 2004). Our results may contribute to an explanation of why firms in these regions have experienced unusually high rates of

innovation and productivity during the transition to the information age. Similarly, researchers have argued that variation in IT-related growth observed at the cross-country level may also result from organizational differences in firms located in different countries (Dewan & Kraemer, 2000; Bloom, Sadun, & Van Reenen, 2007, 2008). Therefore, policy makers may benefit from understanding how IT returns are impacted by differences in the organizational structures that are prevalent in a particular region, or in the mechanisms in place to facilitate the diffusion of organizational innovations among firms.

To test the hypothesis that a firm's external focus is an important determinant of returns to IT investment, we combine data from several sources. Our organizational practice data is collected from a primary survey administered to over 250 firms in 2001. In addition to questions related to workplace decentralization, our survey includes questions about firms' external information practices, such as whether firms regularly use competitive benchmarking, whether project teams include employees from partners and suppliers, and whether the recruiting of new employees is heavily emphasized. The incorporation of these questions into our survey was motivated by existing research that highlights the role of external focus for information age firms (Mendelson, 2000), and the measurement and incorporation of these external constructs into IT demand and productivity analyses is the key contribution of this paper.

An additional contribution of our study, however, is that our survey includes direct measures of firms' product development capabilities. Therefore, in addition to testing how external information practices affect productivity, the availability of product development measures allows us to test a key mechanism, hypothesized in this and earlier studies, through which this system of complements affects productivity. We use our cross-sectional survey data to examine not only how the hypothesized complements vary among firms, but also how they are associated with firms' product strategies. We then combine our cross-sectional survey data with longitudinal data on firms' production and IT inputs, following earlier research that treats organizational practices as quasi-fixed in short panels (Bresnahan, Brynjolfsson & Hitt, 2002). This assumption, which we test using data on organizational adjustment

costs, allows us to investigate how differences in organizational structures impact the productivity of IT investments using both cross-sectional and longitudinal variation in IT investment levels.

Our findings indicate that a firm's external focus is an important determinant of IT value. We find that measures of IT intensity, workplace organization, and external focus are highly correlated and are associated with faster product cycles, indicating that firms with this system of practices in place are able to more rapidly innovate, develop, and deliver new products to market. Our productivity estimates indicate that the most productive firms jointly adopt information technologies along with practices promoting decentralization and external focus. Furthermore, after accounting for these organizational complements, IT intensity is only significant in our regression estimates when accompanied by decentralization and external focus. The output elasticity of IT investment form firms that are one standard deviation above the mean in terms of decentralization and external focus is between 8-9%. A final contribution of our paper is that we show that our estimates are robust to IV regressions that use data on organizational adjustment costs to address the potential endogeneity of organizational investment.

Our findings suggest that firms can successfully leverage IT investments if they absorb and respond to more environmental information through networks of customers, suppliers, partners, and new employees. Mounting a more effective response to the greater inflow of external information requires firms to have the mechanisms in place through which to absorb this information, as well as the mechanisms to allow effective local information processing. Therefore, internal workplace organization, external information practices, and information technologies are part of a mutually reinforcing cluster associated with faster product cycles and higher productivity, especially in environments characterized by rapid technological change. In the next section, we describe the theoretical underpinnings of this research. Section 3 describes the methods and data that we use to explore the relationships between our technological measures, organizational practice data, and firm-level outcomes. In Section 4, we present our findings. Finally, we discuss our conclusions.

Theory

The contribution of IT to business value continues to be a central theme in the academic literature on information systems. Although researchers have convincingly demonstrated that information technologies make a substantial contribution to productivity (Oliner & Sichel, 2002; Brynjolfsson & Hitt, 2003), interest remains in understanding the organizational, environmental, and competitive factors that affect the relationship between IT and business value (Melville, Gurbaxani, & Kraemer, 2004). One leading hypothesis for why IT investments appear to produce supernormal returns in productivity studies is that they also reflect returns to correlated but unobserved organizational assets (Dedrick, Gurbaxani, & Kraemer, 2003). Therefore, like other general purpose technologies such as the steam engine or the electric dynamo, the value of information technology investments is magnified when firms co-invest in complementary workplace innovations and organizational practices (Attewell & Rule, 1984; Zuboff, 1988; David, 1990; Bresnahan & Trajtenberg, 1995). A theoretical basis for why unique combinations of IT and organization produce value for firms can be found in the complementarities literature, which demonstrates that superior performance is produced by systems of mutually reinforcing practices, each of which must be implemented to achieve performance benefits (Milgrom & Roberts, 1990).

These findings have motivated a substantial empirical literature focused on using micro-data to identify these "organizational complements", as well as to test for complementarities and estimate how differences in firms' organizational endowments impact the productivity of information technology investments. Because information technologies lower the costs of information processing within the firm, much of the existing empirical literature on complementarities between IT and organization has focused on workplace innovations such as the decentralization of decision rights within the firm. Bresnahan and colleagues find that workplace reorganization and information technology lead to greater productivity, and argue that these productive benefits are derived through increased product variety (Bresnahan, Brynjolfsson, & Hitt, 2002). Brynjolfsson, Hitt and Yang include organizational variables that measure decentralization in market value regressions and find that investors reward firms that invest in information technologies, but only when they have also made the appropriate organizational investments (Brynjolfsson, Hitt, and Yang, 2002).

Although these studies have focused primarily on organizational differences related to internal information processing, the recent IS literature has also emphasized how information technologies facilitate firm's external information practices related to customers and supply chains (Straub & Watson, 2001). Indeed, scholars have examined a variety of specific ways in which information technologies facilitate access to external information such as through interaction with suppliers (Clemons & Row, 1988), customers (Von Hippel, 2005), and by increasing the relative importance of external labor markets (Cappelli, 1993). These observations are consistent with the theoretical literature on the information processing view of the firm, which argues that increasing the firm's internal information capacity requires new sources of external information in order for changes to yield substantial productivity benefits (Galbraith, 1973; Radner, 1993). Thus, the economic returns to decentralization and IT may be substantially affected by a firm's ability to promote new sources of cross-boundary information flows through new organizational practices.

These arguments are further substantiated by recent work on innovation. Although historically, much innovation occurred in the insulated R&D departments of large firms, in the modern innovative environment, collaborating firms often receive product ideas through customers, suppliers, partners, or new employees, which has led many researchers to focus on the network, rather than the firm, as the more important locus of innovation in the information age (Powell, Koput & Doerr, 1996; Bradley & Nolan, 1998; Mendelson, 2000; Tsai, 2001). Scholars have focused on a variety of mechanisms through which firms can gain access to knowledge from the external environment. For instance, in some regions characterized by quickly changing skills, employee mobility appears to be an important mechanism for the transfer or knowledge related to new products and technologies (Saxenian, 1994; Almeida, Song, & Wu, 2003; Tambe & Hitt, 2008a). Firms also often use alliance structures to gain access to the capabilities and knowledge assets of other firms (Powell, Koput, & Doerr-Smith, 1996; Schilling and Phelps, 2007). The use of competitive benchmarking as an organizational practice has also been identified as an important source of information about industry competitors (Mendelson, 2000; Lynch, 2007). Cross-functional project teams, participation in industry consortia, and direct interaction with

customers for product feedback may also be important "receptors" through which firms can stay abreast of information from their external environments.

Despite this rich theoretical foundation, there is currently little empirical support for the argument that these external information practices are complementary to decentralized decision architectures or IT investments. One notable exception is that in the set of papers closest to ours, Mendelson and Pillai combine various perspectives from the information processing literature in their conceptualization of the "information-age organization". Using data from firms in the computer industry, they find evidence that information-age organizations combine decentralized decision architectures, external information awareness, and activity focus to accelerate product cycles in the computer industry (Mendelson and Pillai, 1998; Mendelson, 2000). Indeed, although investments in information technology and organization are likely to influence productivity in a variety of ways, researchers have argued that product development is a primary mechanism through which organizational complements affect productivity (Bresnahan, Brynjolfsson, & Hitt, 2002). A key hypothesis during the early 1990's was that the benefits of computing were not immediately apparent because IT investments primarily improved product variety, which is poorly captured in economy-wide productivity statistics (Brynjolfsson, 1993). However, by using information technologies to increase efficiency, lower setup times, and move decision authority to line workers, firms have been able to use customized production to support new business strategies (Milgrom and Roberts, 1990). Recently, some researchers have used micro-data to explicitly test the hypothesis that information technologies affect product customization and the breadth of a firm's product line. Gao and Hitt used trademark data to demonstrate that firms that use information technology have broader product lines (Gao & Hitt, 2004). Bartel and colleagues used plant-level data from valve-manufacturing and demonstrated that plants that the lower setup times enabled by information technologies allowed firms to move towards customized, small batch production (Bartel, Ichniowski, & Shaw, 2008).

There is also substantial support for these ideas in the product development literature, which has focused on computerization as a way for firms to deal with greater information demand in risky and uncertain environments. This literature has emphasized both improvements to internal information

processing and access to external information as important ways in which information technologies can affect a firm's product innovation and development capabilities. Scholars have argued that the modern product development process requires significant collaboration at all stages of the product development process, and have identified information technologies as an important tool with which firms manage this flow of information, as well as an important area for future product development research (Ulrich & Krishnan, 2001). Internally, the use of computers for rapid internal communication across dispersed employees and the ability to use database and CAD software to build new products from an existing knowledge base have been identified as ways in which computers improve the speed and effectiveness of product development efforts (Ozer, 2000). However, information systems also enable companies to gather product-related information from external actors. For instance, information systems bring together members of geographically dispersed R&D teams from different organizations to quickly bring new products to market (Wheelwright & Clark, 1992; Lipnack & Stamps, 1997; Boutellier, et al, 1998). Computers also help firms gather product requirements. For example, British Petroleum invested in a global communication network that allowed it to collect customer feedback for all of its products, and IBM and Lotus use information systems to collect product feedback from their customers and business partners (Ozer, 2000).

Therefore, there is substantial support for the argument that external information practices, decentralized decision structures, and information technologies form a cluster of practices that define modern firms and the modern product development process. In this paper, we directly test this hypothesis in the context of complementarities with IT investments. In Figure 1, we diagram the theoretical model that we test in this paper. In the next section, we describe the data we use to test our hypothesis. We then present our results and our conclusions.

Data and Measures

Our organizational practice measures are generated from a survey administered to 253 senior human resource managers in 2001.[1] The questions extend a previous wave of surveys on IT usage and workplace organization administered in 1995-1996 (see Bresnahan, Brynjolfsson, & Hitt, 2002), by incorporating additional questions on internal and external information practices motivated by research on IT and organizational design (Mendelson & Pillai, 1998). Our survey also includes questions related to firms' human capital mix, including occupational and educational distributions. Definitions, variable names, and descriptive statistics for the organizational practice and human capital questions are shown in Table 1. To test our hypothesis, we used the survey responses to construct measures of firm's internal workplace organization and external focus. We combined these measures with data on information technology and production inputs from other sources. We describe the construction of our measures below.

Workplace Organization

Our internal workplace organization variable is based upon a measure motivated by an extensive literature on "high performance work systems" (Ichinioski, Kochan, Levine, Olson and Strauss, 1996) that has been used in a number of earlier studies and has been shown to have reliable properties for measuring organizational assets in large firms across multiple industries (Bresnahan, Brynjolfsson, and Hitt, 2002; Brynjolfsson, Hitt and Yang, 2003). It includes several related measures of the importance of decentralized decision making and self-managing teams among workers, including:

1) the use of teams in production (*SMTEAM*) ,

2) the use of team-building activities (*TEAMBLD*),

3) the use of teamwork as a promotion criterion (*PROMTEAM*), and

4) the use of quality circles (*QUALCIR*).

Chronbach's Alpha for these four measures was 0.732. We also includes two additional measures that capture individual employee level decision making:

[1] The survey questions used in this analysis are shown in the Appendix.

5) the extent to which individual workers decide the pace of work (*PACE*)

6) the extent to which individual workers decide methods of work (*METHOD*)

We combined these measures to create a single measure of internal workplace organization, where each factor is first standardized (STD) by removing the mean and then scaling by its standard deviation, yielding a measure of workplace organization with a zero mean and a standard error of one.

WO = STD(STD(*SMTEAM*) + STD(*TEAMBLD*) + STD(*PROMTEAM*) + STD(*QUALCIR*) + STD(*PACE*) + STD(*METHOD*))

Chronbach's Alpha for the set of individual workplace measures was 0.671. We chose this variable for several reasons. The variables in *WO* capture much of the variation across firms in workplace organization. Moreover, our specific definition of *WO* has been found to be a useful summary metric – the only non-noise factor in a principal components analysis – in earlier work by Brynjolfsson and Hitt (1997). Second, it has an obvious economic interpretation in terms of decentralized, team-based decision-making. Finally, *WO* as a concept of workplace organization is relatively narrow and specific. This makes our model and econometrics more precise and interpretable. Since our data on organizational characteristics are based on a snapshot at the end of the sample period, we do not know whether each firm had the same organizational characteristics throughout the sample period. Yet, it is likely that many of the firms were in the process of adopting these practices during the sample period. In a measurement sense, much of the *WO* that we measure reflects changes in *WO* over the sample period.

External Focus

To construct our external information measure, we focused on three key measures from our organizational survey that reflect constructs that have been highlighted in the literature on firms' external learning mechanisms. Competitive benchmarking (*BENCHMARK*) indicates awareness of the practices and performance of the best performers in the industry, and is a common measure of external information awareness in the literature on organizational innovation (Mendelson, 2000; Lynch, 2007). A second determinant of external focus is interaction with external actors, such as suppliers, customers, or partners

(Von Hippel, 1988). To gauge the extent of this interaction, we included a measure of whether customers, suppliers, and partners were commonly made part of project teams (*PROJTEAM*), and whether firms are generally among the first to adopt new technologies in their respective industries (*NEWTECH*). Finally, the flow of human capital among firms has been shown to be an important way in which firms access information about new products and technologies, especially in industries characterized by fast product cycles (Saxenian, 1994; Song, Almeida, & Wu, 2003). We measured the firm's emphasis on recruiting new talent by asking whether executives dedicated significant time to recruiting (*EXECRCRT)*, and whether respondents agree with the statement that they are successful in attracting new employees because they pay better than industry average (*ATTRACTEMP*). The full form of our external focus variable is shown below.

$$EXT = STD(STD(BENCHMARK) + STD(NEWTECH) + STD(PROJTEAM) + STD(EXECRCRT) + STD(ATTRACTEMP))$$

Chronbach's Alpha for the individual external focus variables is 0.493. We combined these measures in a similar manner to our internal workplace organization variables, where each factor is first standardized (STD) by removing the mean and then scaling by its standard deviation, yielding an external focus measure with a mean of zero and a standard error of one. The measurement and incorporation of this construct into our productivity analysis is the key contribution of this analysis, and is intended to measure whether firms have implemented a set of "receptors" to capture external information, or if instead, they remain insular.

Organizational Inhibitors

Some of our analyses are based on the assumption that the organizational measures described above are exogenous over short time periods, which is theoretically justified by a large literature on organizational adjustment costs (Applegate, Cash & Mills, 1988; Attewell & Rule, 1984; David, 1990; Milgrom & Roberts, 1990; Murnane, Levy & Autor, 1999; Zuboff ,1988; Bresnahan &Greenstein, 1997). However, in addition to organizational practice variables, our survey data includes questions on individual inhibitors of organizational change, allowing us to create direct measures of organizational adjustment costs, which

we can use as instrumental variables for our organizational asset measures. These survey questions ask respondents to describe the degree to which the following factors facilitate or inhibit the ability to make organizational changes: Financial Resources, Skill Mix of Existing Staff, Employment Contracts, Work Rules, Organizational Culture, Customer Relationships, Technological Infrastructure, and Senior Management Support. These responses are used as instruments in both our product development and productivity regressions, as well as to create an aggregate adjustment cost measure which was computed as the standardized sum of the standardized sums of the individual inhibitors. Chronbach's Alpha for the eight individual inhibitors was 0.745.

Product Cycles, Innovation, and Technological Change

Our hypothesis is that external focus affects productivity by enabling firms to be more innovative with respect to product strategy. In addition to providing data on organizational practices, our survey data includes information on managers' assessments of their product capabilities, allowing us to directly test this relationship between organizational practices, IT, and product development. We use three variables to measure a firm's product capabilities with respect to its competitors. The first indicates whether a firm is generally the first to introduce a new product in its industry (*FIRST*). The second measures the speed of internal product development once a new product has been approved (*SPEED*). The third measures whether a firm regularly weeds out marginal products (*MNG*), and is a measure of how effectively a firm's product line is managed. Access to different product development variables is useful because while introduction of new products is related to innovation and the firm's ability to collect and process external information, product development speed and product line management should be more closely associated with the ability to process information within the organization. All of our product development measures are standardized to have a zero mean and standard deviation of one.

Information Technology

Our survey data includes two measures of computerization that can be compared with our cross-section of organizational variables. Responding managers were asked both the percentage of workers in the organization that used personal computers *(%PC*), as well as the percentage of workers in the organization that used email *(%EMAIL*). However, these internal measures are only available in the survey base year. To construct our data set for the longitudinal productivity analysis, we use panel IT measures based on an external data set describing firm-level IT employment over the last two decades, which we use as a proxy for firms aggregate IT expenditures. Although aggregate firm-level IT expenditure data has been used in some recent studies on IT investment, it is generally survey based, available only for a small sample of firms, and therefore difficult to combine with other data sets. By contrast, larger archival datasets such as the CITDB capital stock data or our employment data, although imperfect measures for total IT expenditure, are generally available for much longer timer periods, and for a larger sample of firms.

The IT employment data set, the measure construction, and their sampling properties are described in greater detail in other work (Tambe & Hitt, 2008b). IT employment in this data set is estimated using the employment history data from a very large sample of US based information technology workers. For our purposes, this employment-based data set is superior to alternative archival data sets, such as the CII capital stock data, in several ways. Although recent research on IT productivity has increasingly relied on the Computer Intelligence Technology Database (CITDB), the main panel of these data are restricted to Fortune 1000 firms, the definitions of variables changed significantly after 1994 and most importantly, the CITDB no longer includes direct measures of IT capital stock.[2] Because the CII capital stock data are reliably available only through 2000,[3] a panel around a post-2000 base year

[2] Chwelos, Ramirez, Kraemer and Melville (2007) provide a method for extending CITDB 1994 valuation data through 1998 by imputing the values of equipment in the earlier part of the dataset and adjusting for aggregate price changes. However, this differs from the method employed by Computer Intelligence which determined equipment market values by looking at actual prices in the new, rental and resale computer markets.

[3] Part of the reduction in utility of the CITDB as a measure of IT capital stock is due to the fact that the original methodology, interviewing data center managers at each production site, was much more effective in capturing centralized IT assets such as mainframes than PCs or outsourced systems. However, the decentralized and

cannot be constructed. Our employment-based data, by contrast, are reliably available through 2006. Furthermore, this employment-based data set has been shown to be highly correlated with other available IT capital, employment, and labor expense data, suggesting that it is a reasonable proxy for aggregate IT expenditure.[4] Finally, because our employment data set is available for a much larger sample of firms than the capital stock data including non Fortune-1000 firms, it triples the number of firms in the survey for which IT measures and organizational practice data are available. Using this data set, we construct measures of the total number of IT workers in a given firm-year, as well as the percentage of a firm's employees that are IT workers. In most of our analyses, we use the latter variable because it is scaled for size, making it comparable to other available measures that are scaled for size, but we use total IT employees in our production model which requires labor inputs to be included in levels.

Descriptive statistics and correlations for the IT employment measures and the survey based IT measures are shown in Table 2. The mean usage of both PCs and email for firms in our sample is about 60%. By comparison, similar measures from a survey conducted in 1995 indicated that in the average firm, about 50% of workers used computers, and only about 30% of workers used email, implying significant growth in IT intensity in the six years interim period. The average firm in our sample had about 470 IT workers in 2001, comprising about 2.3% of total employment, compared to 2.2% of total employment accounted for by workers in "Computer and Mathematical Occupations" in the BLS 2001 Occupational Employment Survey.[5] The large standard deviation for our measures of the fraction of IT workers, email use, and computer use suggests that some firms, such as those in IT-producing industries, have much greater IT usage than others. Therefore, we log transform our IT measures to facilitate linear comparisons with our organizational factor data.

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distributed structure of IT infrastructure in modern firms makes it less likely that respondents in the central IT function can adequately characterize firm-wide IT use.

[4]Correlations between our employment data set and other well known data sets, such as the CITDB, ComputerWorld, and InformationWeek data sets are provided in Tambe & Hitt, 2008.

[5] Available at http://www.bls.gov/oes/

Value Added and Non-IT Production Inputs

Longitudinal data on capital, labor, R&D expense, and value-added were obtained for the firms in our sample by using the Compustat database. Measures were created from these data using standard methods from the micro-productivity literature. Price deflators for inputs and outputs are taken from the Bureau of Labor Statistics (BLS) and Bureau of Economic Analysis (BEA) web sites. Eight industry dummies were created using 1 digit NAICS headers. Table 3 shows statistics for the 2001 cross section of the Compustat variables included in our analysis. In 2001, the average firm in our sample had about 3.8 billion dollars in sales and 15,200 employees.

Methods

Access to cross-sectional organizational and innovation data as well as to panel data on IT and other production inputs allows us to test several implications of our complementarities hypothesis that we describe in further detail below.

Correlations

Using our cross-sectional data, we can first examine how the use of IT and the proposed complementary practices co-vary in the survey base year. If these innovations are complements, price declines in IT should be accompanied by greater use of both complementary organizational practices.

Product Development Regressions

We can also use cross-sectional survey data to develop some insight into *how* these inputs affect the productivity of firms. We argue that external focus is part of a cluster of practices that affect productivity through a variety of mechanisms, such as product innovation and product mix. To test this proposition, we test how our organizational and IT variables contribute to various stages of the product development process.

$$PROD_i = \beta_{EXT} EXT_i + \beta_{WO} WO_i + \beta_{IT} IT_i + \beta_{RD} RD_i + controls$$

PROD represents one of our possible three product development outcomes (*FIRST, SPEED,* and *MNG*), *EXT* is our external focus variable (EXT), *WO* measures workplace decentralization, *IT* is a measure of IT usage within the firm, *RD* measures R&D intensity computed as the R&D expense per employee, and *i* indexes firms. For our *IT* usage variable, we use the percentage of workers who use email. As control variables, we include dummy variables for industry and the percentage of a firm's workers that are college educated.

One concern with these regression estimates is that our organizational practice variables and product development measures may be simultaneously determined. Therefore, we conduct IV regressions in which the organizational measures (ORG and EXT) are treated as endogenous. As instruments, we use our individual inhibitors of organizational transformation, which reflect the ease or difficulty through which firms can develop these organizational assets, as well as dummy variables that indicate a the location of a firm's corporate headquarters, which may affect a firm's cost for external information gathering.

Productivity Regressions

Finally, we test our main hypothesis, which is that if workplace organization, external focus, and information technology are complements, firms should experience the largest productivity gains when they are adopted together as a system. We test this proposition by embedding our measures within a production function, a framework that has been widely used in IT productivity research (Stiroh, 2004 reviews much of this literature). For example, IT productivity scholars embed measures of information technology, along with levels of other production inputs, into an econometric model of how firms convert these inputs to outputs. Economic theory places some constraints on the functional form used to relate these inputs to outputs, but a number of different functional forms are widely used depending on the firm's economic circumstances.

We use the Cobb-Douglas specification, which aside from being among the simplest functional form, has the added advantage that it has been the most commonly used model in research relating inputs

such as information technology to output growth (e.g., Brynjolfsson and Hitt, 1993, 1996; Dewan and Min, 1997), and has also been used extensively in research testing for complementarities between IT and organization (Bresnahan, Brynjolfsson, & Hitt, 2002; Brynjolfsson, Hitt, & Yang, 2002). Our primary regression model can be written

$$va = \beta_k k + \beta_{nite} nite + \beta_{it} it + \beta_{WO} WO + \beta_{EXT} EXT + \beta_{wo*ext} (WO*EXT) + \beta_{WO*it} (WO*it) + \beta_{EXT*it} (EXT*it) + \beta_{WO*EXT*it} (WO*EXT*it) + u$$

where *va* is the log of value added, *k* is the log of capital, *it* is the log of IT employees, *nite* is the log of non-IT employees, and WO and EXT are our organizational variables. In this model, the organizational variables are entered in levels as well as in interactions with each other and with the technology variables. Dummy variables are included for industry and year. In some specifications, we also control for the firm's human capital.

Although our data on IT and other production inputs is longitudinal, our organizational factors data are based on a single survey conducted in 2001. We construct an eight-year panel (1998-2006) by making the assumption that organizational factors are quasi-fixed in the short run. Because our survey was administered in 2001, in the middle of our panel, this implies that these organizational factors stay relatively fixed in the four-year period beginning and ending at 2001. Similar assumptions regarding the quasi-fixed nature of organizational assets have been used in prior research on organizational factors (Bresnahan, Brynjolfsson, & Hitt, 2002), and the assumption that organizational factors are associated with substantial adjustment costs and take considerable time to change is supported by substantial case and econometric evidence (Applegate, Cash & Mills, 1988; Attewell & Rule, 1984; David, 1990; Milgrom & Roberts, 1990; Murnane, Levy & Autor, 1999; Zuboff ,1988; Bresnahan &Greenstein, 1997). However, in our analysis, we use our adjustment cost data to directly address concerns related to this assumption.

Still, one shortcoming of our empirical approach is that we cannot test the impact of changes in these organizational factors while holding firm factors fixed. Instead, our regression estimates are derived by testing how cross-firm differences in organizational factors influence productive returns to information technology investments, and leave open the possibility that these systems of organizational practices may

reflect other unobserved heterogeneity among firms. However, in our regression results below, we control for the most likely candidate, differences in human capital endowments among firms. Thus, we are able to substantially increase the number of factors that we are able to directly measure over prior work, reducing the role that unobserved heterogeneity plays in the analysis.

Results

Correlations

Table 4 shows partial correlations between IT and our organizational practice variables. All variables are scaled for firm size. We also control for 1-digit NAICS industry, as well as the number of skilled blue-collar workers and the number of clerical workers to control for the nature of the firm's production process. Our external focus measure is correlated with all of our IT measures, and is highly correlated with the decentralization measure. Workplace organization is also positively associated with the IT measures, although it is significantly correlated only with the internal survey based measures. The correlation between workplace organization and external focus is .38 ($p<.01$), indicating that external information practices are significantly more likely to be found in firms with decentralized decision architectures. These correlations support the argument that external focus, workplace organization, and information technology usage are complements in the production process. Our aggregated adjustment cost variable, which we use as an instrument in both our product development and productivity regressions, is negatively and significantly associated with both organizational measures, indicating that firms that have higher adjustment costs are less likely to have implemented these systems of work practices.

Product Cycle Measures

Table 5 shows associations between product development measures and our technology and organizational variables. In Columns (1)-(3), we report OLS regressions of how our different

organizational practice and IT measures affect product development. In Column (1), the dependent variable is how likely a firm is to be the first in its industry to introduce a new product. The point estimate on external focus is positive and significant (t=3.44), suggesting that less insular firms also tend to exhibit product leadership. The dependent variable in Column (2) is related to internal product development speed, which captures how quickly a firm can introduce a new product or service *after* it has been approved. Thus, this measure captures speed of execution, rather than innovation. The estimates in Column (2) indicate that in addition to R&D intensity, technology usage, rather than organizational variables, is more closely associated with faster internal product development (t=2.12). The dependent variable in Column (3) is effective management of the product line, and the coefficient estimates indicate that external focus (t=3.16) and to a lesser degree, decentralization (t=1.69), are most closely related to how tightly a firm can manage its product line .

In Columns (4)-(6), we report estimates from 2SLS regressions where our organizational measures are treated as endogenous, and individual inhibitors of organizational transformation and location variables are used as instruments. As in our OLS regressions, the estimates from this set of regressions indicates that external focus is positively and significantly associated with new product introduction (t=3.26), and that IT investment is most closely associated with product development speed (t=2.19). However, in our IV estimates, decentralization rather than external focus appears to be most closely associated with effective management of the product line (t=2.18). Furthermore, Hausman test statistics from all three IV regressions, displayed at the bottom of Table 5, indicate that we cannot reject the null hypothesis that decentralization and external focus are exogenous to our regression models, consistent with our assumption that organizational factors are difficult to change in the short-run.

In aggregate, this set of results indicates that the ability to exercise product leadership is more closely connected to a firm's ability to capture ideas from other actors in its network, but its ability to internally process and manage products internally in a timely manner is governed by its internal information processing capacity. In quickly changing product environments, therefore, external receptors are needed in addition to decentralization and technology.

Productivity Regressions

The central hypothesis of this paper is that external focus is an important organizational asset affecting the returns to IT investment, especially when combined with decentralization. Table 6 shows the results from our regressions directly testing this hypothesis in a complementarities framework. All estimates are from pooled OLS regressions, and errors are clustered by firm to provide consistent estimates of the standard errors under repeated sampling of the same firms over time. First, we establish a baseline estimate of the contribution of IT to productivity during our panel, which extends from 1998 to 2006. The coefficient estimate on our IT investment variable is about .076 (t=2.0), consistent with many pooled OLS regressions of this type that appear in the literature using other sources of data on IT expenditures (Brynjolfsson & Hitt, 1996). In Column (2), we include only decentralization measures, for comparison with earlier studies. Both the coefficient estimate on decentralization and the interaction term are insignificant, perhaps because the more accurately measured employment-based IT variable is increasingly indistinguishable from decentralization. The coefficient estimate on IT is slightly smaller, but is close to the estimate without any organizational factors explicitly modeled. In Column (3), we include only our external focus measure plus an interaction term with information technology. Both the external focus measure and the interaction term are insignificant. In our main results, reported in Column (4), we include the full set of organizational factors and interaction terms. In our complete specification, the coefficient estimates on the three-way interaction term, as well as the two-way interaction term between external focus and decentralization are positive and significant. Furthermore, after including the organizational factors and interaction terms, the IT main effect coefficient estimate is not significantly different from zero. Although our benchmark estimates in Column (1) indicate an output elasticity of 7-8%, our Column (4) estimates suggest that these benefits are only captured by firms which are above average with respect to both decentralization and external focus.

One concern with these estimates is that because we cannot perform fixed-effects tests, unobserved firm factors or unobserved productivity shocks may bias the estimates on our interaction terms. Fortunately, our survey data allow us to address these concerns in a number of ways. The first

concern is that organizational changes may be accompanied by changes to the firm's human capital and skill mix, which have also been shown to be complementary to technology adoption (Bresnahan, Brynjolfsson, & Hitt, 2002). In Column (5), we includes controls for workforce composition (percentage of skilled workers and professionals out of total employment) to ensure that our interaction terms are not reflecting returns to human capital. Our coefficient estimates do not change substantively after including these human capital measures.

A second concern is that our estimates may reflect unobserved shocks that simultaneously increase productivity and organizational investment. In Column (6), we treat external focus and decentralization as endogenous and use the individual inhibitors as instruments for the organizational measures as well as for all interaction terms formed between these organizational measures and between the organizational and IT measures. The IV estimates are similar to those in earlier regressions and indicate that our results are unlikely to be reflecting unobserved shocks. At the bottom of Column (6), we report values of the Hansen J statistic, which tests the exclusion restriction, and the Anderson Canonical Correlation, which tests for weak instruments. The reported values indicate that instrument validity is not likely to be a problem in our IV regression model. Furthermore, the value of the Hausman statistic suggests that we cannot reject the null hypothesis that our organizational measures are exogenous, and that our OLS regressions in Columns (1)-(5) produce consistent estimates.

Additional Robustness Tests

Our IV estimates in Table 6 provide support for the argument that the differences in organizational measures are not being driven by productivity differences. However, to provide additional support for the argument that organizational measures are exogenous, we also conduct some sub-sample regressions to investigate the sensitivity of our results to this quasi-fixed assumption. If external focus is complementary to technology adoption and decentralization, it is likely that many of the firms in our 2001 sample were in the process of adopting practices associated with increased external focus during the sample frame. Therefore, our 2001 snapshot may understate organizational differences among firms in

our sample prior to 2001, and overstate them in the post-2001 period, raising the question of how much our productivity estimates are influenced by error in our organizational measures.

There are a number of additional tests (beyond the instrumental variables regressions reported earlier) we can conduct to examine whether our results are sensitive to the assumption that organizational factors are exogenous during our sample period. First, we can compute an aggregate adjustment cost measure based on the standardized sum of the standardized values of the responses to the questions on inhibitors and facilitators of organizational change that we used previously as instruments. We create the scale to allow the sample to be segmented based on firms with the very highest and very lowest adjustment costs. Firms facing the highest adjustment costs are likely to have been endowed with their organizational complements, while firms with lower adjustment costs are more likely undergoing change to more modern work practices. Thus, if unusually high performing firms are also likely to be investing in ORG we would expect the endogeneity problem to be concentrated in the low adjustment cost firms. In Columns (1) and (2), we report regression estimates for the subsamples of firm that have lower than average and higher than average aggregate adjustment costs, respectively, and find results that suggest our analyses are not biased upwards by endogeneity. The coefficient estimate on the three-way interaction term for firms with lower organizational adjustment costs is .085, very similar to our baseline estimate (t=2.30). The comparable coefficient estimate for firms with high adjustment costs, for whom our assumption of quasi-fixed organizational factors is more likely to be accurate, is .140 (t=2.98). Therefore, it appears that to the extent that our organizational factors are changing during the sample period, it would introduce a downward bias to our estimates.

We can also test these assumptions by varying the length and sample frame of our panel. In Column (3), we restrict our panel to a four-year panel around 2001, so that our organizational measures are more likely to be accurate because the panel encompasses a shorter time span. Our estimates from this regression are very similar to our main eight-year estimates in Table 6. In Columns (4) and (5), we run separate regressions on the years before and after 2001. The higher coefficient estimate in the pre-2001 period is consistent with the interpretation that our survey measures are likely to understate

organizational differences before 2001 and overstate them after 2001. Overall, our estimates in Columns (1) through (5) suggest that even if firms were becoming more externally focused during these years, measurement error in organizational factors is unlikely to have had a significant effect on our estimates, and certainly should not have biased our estimates upwards.

Conclusion

Our results suggest that in modern firms the system of complements that includes decentralization, external focus, and IT intensity is closely associated with productivity. IT is positively and significantly associated with productivity, but only for firms that through investment or luck, have the right organizational structures in place. While prior work has already demonstrated the importance of decentralization in explaining differences in returns to IT investment, the central contribution of this paper is to demonstrate that a firm's external focus is another important factor in determining this variance to IT productivity.

Our hypothesis is supported by a number of different tests. First, information technology, decentralization, and external focus are highly correlated, indicating that firms are likely to invest in these factors together. We also showed that these external and information practices are associated with product development capabilities, providing evidence that one of the principal mechanisms through which external focus affects productivity is likely to be product development. We also find evidence of complementarities in the production function—the combination of IT, decentralization, and external focus is positively associated with firm productivity. Moreover, when these complements are included in a production model, main effect estimates of IT and other organizational factors disappear, indicating that firms derive the most benefit from implementing the system of technological and organizational resources.

From a research perspective, our study contributes to a literature on determinants of IT value, and in particular, on IT-related organizational complements. Our findings highlight the benefits of information

technologies in an environment in which innovation largely takes place among networks, rather than within the R&D departments of insular firms. Information technologies appear to provide greater benefits for firms that must process information effectively to respond to rich information flows within their network. Therefore, some of the variance in returns to IT investments that have been observed among firms, as well as cross-regional and cross-country differences in returns to IT adoption, may be due to the growing importance of networks in production. Furthermore, our results may help to explain why some regions appear to have benefited disproportionately from the IT investment boom. For instance, the degree to which firms, suppliers, and customers are "networked" may differ substantially among countries and among regions within the same country. Finally, from a research methods standpoint, we appear to have found an effective set of instruments for work organization and external focus, providing greater confidence that prior results on the benefits decentralized work practices are not driven by endogeneity.

A key managerial implication of our research is that "extroverted" firms are more productive and derive disproportionate benefits from recent advances in IT and workplace organization. This is consistent with the idea that IT allows firms to store, transmit and process more information from their environment. Companies that exploit this opportunity by using more information from customers, suppliers and even competitive benchmarks appear to outperform their rivals. Moreover, theoretical arguments suggest that managers should implement all of the elements in a system of complements to realize the maximum benefits (Milgrom & Roberts, 1990). Therefore, managers in firms with decentralized structures may not realize productive returns to IT-related investments unless they find a way to also promote cross-boundary information flows through external practices such as competitive benchmarking and inter-organizational product teams. However, it is likely that our measures represent a much wider set of practices that firms use to bring external information into the organization.

Our findings may also have implications for policy makers. There has been much recent discussion of why IT appears to have led to much greater productivity growth in some regions within the US than in others, and in some parts of the world than others (Dewan & Kraemer, 2000; Van Reenen,

Sadun, & Bloom, 2008). A leading hypothesis explaining this phenomenon is differences in organizational factors among countries. For instance, researchers have shown that decentralization is much more likely in some countries than in others, due to economic and even religious differences (Van Reenen, Sadun, & Bloom, 2007). Our findings suggest that the degree to which firms are networked is a potentially important factor explaining differences in IT led productivity growth. Even within the same industry in the US, scholars have shown that considerable variation can exist among the degree to which firms are networked across regions (Saxenian, 1994). Differences across countries are likely to be even more pronounced.

We recognize that there are some limitations to our study. Because of the research design, we were not able to conduct fixed effect productivity regressions to determine if changes in organizational assets drive productivity changes. Thus it is possible that the organizational assets that we have focused on here are reflecting some unobserved heterogeneity among the firms in our sample. However, we controlled for the most likely candidate, human capital endowments, and supplementary data allowed us to test whether our results were sensitive to this assumption. In the future, however, a research design which included repeated waves of organizational surveys may be an interesting extension to this research, as well as research investigating how and why firms adopt these organizational practices. We have just begun to identify and classify the organizational assets that complement the productivity of IT investments. Future research using more fine-grained measures of organization will help to advance this research stream.

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Figure 1

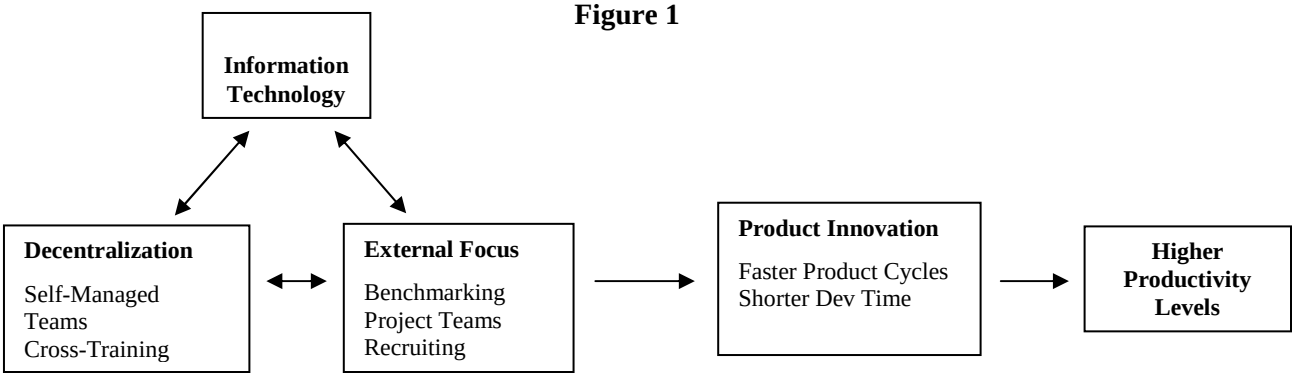
Information Technology
Decentralization
Self-Managed Teams
Cross-Training
External Focus
Benchmarking
Project Teams
Recruiting
Product Innovation
Faster Product Cycles
Shorter Dev Time
Higher Productivity Levels

Table 1: Organizational Practice and Human Capital Survey Variables

	Range	N	Mean	Std. Dev.
External Focus				
We regularly use competitive benchmarks	1-5	233	3.58	1.06
Project teams include suppliers, partners, customers	1-5	227	2.21	1.10
Adopt New Technologies	1-5	225	3.10	1.09
Executives spend significant time recruiting	1-5	247	2.15	0.82
Successful Attracting New Employees	1-5	239	2.92	0.92
Decentralization				
Self-managing teams	1-5	249	2.39	1.15
Cross-training	1-5	250	3.29	0.98
Team-building activities	1-5	249	2.70	1.04
Quality circles	1-5	243	2.51	1.17
Promotion based on teamwork	1-5	245	2.38	1.14
Who decides pace of work (5=employees)	1-5	252	2.48	0.75
Who decides method of work (5=employees)	1-5	251	2.78	0.83
Product Cycles and New Technology Adoption				
Typically first to introduce new products	1-5	218	3.22	1.08
Leading edge adopter of new technologies	1-5	225	3.10	1.09
Weed out marginal product lines	1-5	208	3.34	0.99
Human Capital Variables				
% College	0-90	206	20.2	20.0
% Professional	0-79	227	22.6	18.6
% Skilled	0-88	227	23.6	20.5

Table 2: Means, Standard Deviations, and Correlations for IT Measures

	Variable	N	Mean	Std. Dev.	Min	Max	1	2	3
1. % IT Employees	*%IT EMP*	177	2.3	2.2	.1	16.2	1.0		
2. % Use PC[†]	*%PC*	171	63.7	29.9	0	100	.23	1.0	
3. % Use Email[†]	*%EMAIL*	171	61.3	30.4	0	100	.21	.85	1.0

Table 3: Production Function Variables

	Variable	Mean	Std. Dev.
2001 Cross Section			
Log(Sales)	*LSALES*	6.80	1.77
Log(Value Added)	*LVA*	5.73	1.80
Log(Employment)	*LEMPLOY*	8.44	1.66
Log(Non-IT Employment)	*LITEMPLOY*	4.61	1.68
Log(Capital)	*LCAP*	6.01	2.02
N=181			

Table 4: Correlations Between Organizational Measures, IT Measures, and Organizational Inhibitors

	External Focus (EXT)	Decentralization (WO)
Log(% Email)	.24**	.28**
Log(% PC)	.18**	.19***
Log(%IT Emp)	.16**	.09
ADJ	-.24***	-.28**
WO	.45***	

Partial correlations controlling for industry, % professional workers, and % skilled workers. N=160-210, due to non-response. *p<.1, **p<.05, ***p<.01. Test is against the null hypothesis that the correlation is zero. ADJ is the aggregate measure of inhibitors of organizational transformation.

Table 5: Regressions of IT and Organizational Practices on Product Development Measures

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	FIRST	*SPEED*	*MNG*	*FIRST*	*SPEED*	*MNG*
	OLS	OLS	OLS	2SLS	2SLS	2SLS
External Focus (EXT)	.310 (.090)**	-.076 (.097)	.294 (.093)**	.437 (.134)**	-.045 (.144)	.078 (.141)
Decentralization (WO)	.040 (.086)	.0125 (.093)	.152 (.090)*	-.149 (.145)	.007 (.157)	.335 (.154)**
Log(%Email)	.051 (.117)	.267 (.126)**	-.170 (.123)	.085 (.119)	.281 (.128)**	-.154 (.126)
Log(R&D Intensity)	.045 (.072)	.200 (.078)**	.018 (.075)	-.008 (.073)	.175 (.079)**	.045 (.077)
Controls	Industry %College	Industry %College	Industry %College	Industry %College	Industry %College	Industry %College
Hausman Test				p=.143	p=.563	p=.124
R^2	.23	.17	.24	.21	.15	.20
N	135	135	135	128	128	128

**p<.05, *p<.10. All regressions on 2001 cross sectional survey data. *FIRST* is a measure of the extent to which firms are the first to introduce new products in an industry. *SPEED* is a measure of how long it takes to design and introduce a new product after approval. *MNG* is a measure of internal product management, and indicates whether firms regularly weed out marginal products from their product line. Instrumental variables used in 2SLS regressions include individual inhibitors of organizational adjustment as well as state dummies. The Hausman Test tests the null hypothesis that OLS is inconsistent.

Table 6: Regressions of IT and Organizational Practices on Productivity Measures

	1998-2006	1998-2006	1998-2006	1998-2006	1998-2006	1998-2006
	(1)	(2)	(3)	(4)	(5)	(6)
DV: Log(VA)	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**	**2SLS**
Log(IT Employment)	.076 (.038)**	.069 (.037)*	.071 (.039)*	.022 (.037)	-.002 (.040)	-.028 (.048)
Log(Non-IT Employment)	.582 (.056)**	.595 (.053)**	.579 (.057)**	.616 (.048)**	.643 (.055)**	.642 (.066)**
Log(Capital)	.323 (.032)**	.303 (.030)**	.319 (.029)**	.317 (.029)**	.312 (.034)**	.332 (.049)**
WO		.184 (.166)		.103 (.153)	.149 (.141)	.118 (.370)
EXT			.121 (.189)	.014 (.167)	-.068 (.157)	-.027 (.564)
WO x EXT				.429 (.123)**	.387 (.126)**	.847 (.332)**
WO x IT		.020 (.037)		.002 (.032)	.016 (.030)	-.011 (.085)
EXT x IT			.014 (.044)	.006 (.038)	-.016 (.036)	.018 (.136)
WO x EXT x IT				.099 (.031)**	.089 (.032)**	.179 (.080)**
Controls	Industry, Year	Industry, Year	Industry, Year	Industry, Year	Industry, Year, %Skilled, %Professionals	Industry, Year
Hansen J						0.436
Anderson CC						84.7, p<.000
Hausman Test						0.617
R^2	.92	.93	.93	.93	.93	.92
N	813	813	813	813	769	813

*p<.1, **p<.05, ***p<.01, Huber-white robust standard errors are shown in parentheses and clustered on firm. IT Employment, Non-IT Employment and Capital are in logs. Dependent variable in all regressions is Log(Value Added). The Hansen J Statistic tests the null hypothesis that the instrumental variables are uncorrelated with the residual terms (exclusion restriction). Anderson represent the correlations between the endogenous regressors and instrumental variables, and therefore, test for instrument weakness. The Hausman Test tests the null hypothesis that OLS is inconsistent.

Table 7: Sensitivity Tests to Quasi-Fixed Organizational Assumptions

DV: Log(Value Added)	**1998-2006**	**1998-2006**	**1999-2002**	**1998-2001**	**2002-2006**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	Low Adj Cost	High Adj Cost	All	All	All
Log(IT Employment)	.000 (.055)	.067 (.051)	.023 (.041)	-.007 (.056)	.038 (.038)
Log(Non-IT Employment)	.647 (.081)**	.564 (.055)**	.610 (.058)**	.627 (.076)**	.611 (.045)**
Log(Capital)	.294 (.060)**	.333 (.035)**	.311 (.035)**	.319 (.039)**	.312 (.031)**
WO	.155 (.248)	-.259 (.264)	.137 (.188)	.227 (.244)	.024 (.144)
EXT	.055 (.228)	-.034 (.246)	-.219 (.194)	-.400 (.296)	.213 (.154)
WO x EXT	.354 (.159)**	.610 (.186)**	.388 (.150)**	.550 (.231)**	.404 (.117)**
WO x IT	.020 (.053)	-.089 (.055)	.012 (.040)	.032 (.053)	-.015 (.031)
EXT x IT	.020 (.050)	-.007 (.058)	-.053 (.045)	-.094 (.068)	.055 (.035)
WO x EXT x IT	.085 (.037)**	.140 (.047)**	.085 (.038)**	.124 (.057)**	.097 (.031)**
Controls	Industry, Year	Industry, Year	Industry, Year	Industry, Year	Industry Year
R^2	.93	.94	.92	.91	.95
N	424	389	423	316	497

**p<.05, *p<.10. Huber-white robust standard errors are shown in parentheses and clustered on firm. IT Employment, Non-IT Employment and Capital are in logs. Dependent variable in all regressions is Log(Value Added).

APPENDIX: HUMAN RESOURCES PRACTICES SURVEY

Introduction

Thank you for helping with this important research. Based on our testing, we anticipate that this survey will require approximately 15 minutes to complete. This survey contains questions about the business strategy and human resources (HR) policies in your company. To maximize the value of the customized benchmarking report you will receive, please be as accurate as you can. If you don't have the exact information, please provide your best estimation. Your participation in this survey is voluntary and you may refuse to answer any question. Your identity will be kept confidential by the study team and the information you provide will be used for aggregate statistics, and not to specifically identify you or your company to any third parties. If you have any questions about the survey, please call 800-854-8409 ext. 5736.

Section A. Background Information on Core Employees

Questions in this section refer to "Core Employees", defined as *non-managerial, non-supervisory personnel directly involved in producing your company's main product or delivering its main service*.

What percentage of your Core Employees completed the following education levels? (Write percentages in each row representing highest education level obtained. Results should total to 100%)

Education Percent of Core Employees
a. Less than High School _____%
b. High School Degree _____%
c. Some College _____%
d. 4-year College Degree _____%
e. Advanced Degree _____%
f. Total 100%

For the remaining questions in this section, please consider the work practices of Core Employees at your most typical establishment.

To what extent are the following work practices for Core Employees used at this establishment? (check one box in each row)
Practice: Very Heavily, Heavily, Moderately, Somewhat, Not at all
a. Self-managing teams
b. Cross-training
c. Team building and group cohesion activities
d. Employee involvement groups (e.g. "quality circles")
e. Promotion based on teamwork

Which group of employees is typically responsible for the following tasks at this establishment? (check one box in each row)
Exclusively Core Employees, Mostly Core Employees, Equally,Mostly Managers, Exclusively Managers

a. Setting the pace of work
b. Deciding which tasks should be performed
c. Deciding how tasks should be performed
d. Allocating tasks among workers
e. Determining whether quality level is acceptable

Section B. Worker Characteristics

The following questions pertain to the composition of the overall workforce for the ENTIRE COMPANY.

1. What percentage of all employees in your entire company fall into the following occupational categories? (Results should total to 100%)

Occupation Type Percent of All Employees
a. Clerical _____%
b. Unskilled blue-collar workers _____%
c. Skilled blue-collar workers _____%
d. Managers and supervisors _____%
e. Non-managerial professionals _____%
f. Total 100%

C. Company Characteristics

Please rate whether the following factors **at your company** facilitates or inhibits the ability to make organizational changes. (check one box in each row)

Inhibits Significantly, Inhibits Somewhat, No Effect, Facilitates Somewhat, Facilitates Significantly

a. Financial resources
b. Skill mix of existing staff
c. Employment contracts
d. Work rules
e. Organizational culture
f. Customer relationships
g. Technology infrastructure
h. Senior management support

5. What percentage of all employees uses the following technologies in their regular work? (Totals do not add to 100%)

a. General purpose computers (e.g. PC, workstation, or mainframe terminal) _____% of all employees
b. Computerized process controls or machinery _____% of all employees
c. Electronic Mail _____% of all employees
d. Internet or World-Wide Web _____% of all employees

6. On average, how long does it take your organization to perform the following activities? (check one box in each row)

<1 week, 1 month, 3 months, 6 months, 1 Year, 2 Years, >2 Years, Not Applicable

a. Design, create and introduce a new product or service after approval
b. Hire a new core employee once need is identified
c. Respond to a competitor's price change
d. Introduce a new production technology or method

7. To what extent do the following statements describe the work practices and environment of your ENTIRE COMPANY (check one box in each row)

Describes, Completely Describes, Considerably Describes, Somewhat Describes, Slightly Describes, Not at all

a. Executives devote a significant part of their time to recruiting
b. We regularly communicate our financial and strategic goals to everyone in the company

c. Competitive benchmarks are regularly used in corporate strategic planning meetings
d. Managers are significantly penalized for not meeting budget targets
e. Our organization makes a clear separation between line and staff functions
f. Most work at our company takes place in cross-functional teams
g. We regularly use contract workers for non-clerical tasks
h. Project teams often include employees from customers, suppliers or business partners
i. Managers in our company extensively use technology for communication with workers
j. Typical workers in our company extensively use technology for coordination with each other
k. Our company places restrictions on the use of the Internet by employees
l. In our industry, we typically are the first to introduce new products
m. Our company has a lot of standard procedures
n. Our company embeds many procedures in technology
o. We are usually the leading-edge adopter of new technologies in our industry
p. Most of our product ideas are generated by customers
q. Our company regularly "weeds out" marginal product lines
r. Our company encourages open access to internal information
s. For all employees, responding to customer needs takes precedence over any other task
t. We are successful in attracting new employees because we pay better than the industry average
u. Our company stresses operational excellence (efficient execution) over innovation
v. We invest heavily in promoting our corporate culture