

THE EXTROVERTED FIRM: HOW EXTERNAL INFORMATION PRACTICES AFFECT PRODUCTIVITY

La firme extravertie : comment les pratiques d'information externes affectent la productivité

Completed Research Paper

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Abstract

We combine detailed survey data on firms' organizational practices with information technology (IT) investment measures to test the hypothesis that in addition to decentralization, external focus is another important determinant of returns to IT investment. We argue that IT-intensive firms characterized by decentralization are able to more effectively process and respond to information from their competitive environments, which drives productivity through superior innovation and product development. Our estimates from a regression model including organizational practices indicate that IT investments only increase productivity for those firms that are decentralized and externally focused. IT investments in firms that have only one or neither of these organizational assets in place do not appear to significantly increase productivity.

Keywords: Information Technology, Productivity, Organizational Complements, Organizational Design

Résumé

Nous testons l'hypothèse qu'avec les technologies de l'information et la décentralisation, l'ouverture extérieure constitue un troisième élément d'un système complémentaire qui génère une plus forte productivité par le biais d'une meilleure innovation produite. Les firmes caractérisées par la décentralisation et des investissements en TI procèdent et répondent de manière plus efficace à l'information externe. En conséquence, atteindre les bénéfices de productivité liés aux TI requiert des firmes qu'elles mettent en œuvre des pratiques facilitant les flux d'information avec leur environnement.

Introduction

This study examines the importance of an organization's "external focus", the practices that have been put in place to capture and process information from its environment, on generating value from information technology (IT) investments. Our focus on organizational determinants of IT productivity is related to a literature that focuses on

identifying the operational drivers of IT value (Melville, Kraemer, and Gurbaxani, 2004), as well as to a large literature on the importance of organization and workplace innovation to the recent productivity gains experienced by firms in the US economy (Black and Lynch, 2005). A leading explanation for the estimated excess returns to computerization is that some firms, through luck or skill, have the right endowment of organizational structures, processes, and skills to reap superior benefits from the new technologies. For example, researchers have used organizational micro-data to demonstrate that information technologies are associated with greater productivity in firms characterized by decentralized architectures, higher levels of human capital, and team-based production (Bresnahan, Brynjolfsson, and Hitt, 2002; Caroli and Van Reenen, 2002). This system of technological and organizational innovations has been tied to productivity improvements through greater product customization and increased product variety (Bresnahan, Brynjolfsson, and Hitt, 2002; Bartel, Ichniowski and Shaw, 2008).

Although prior research on organizational complements to IT investment has focused primarily on the importance of *internal* workplace factors such as decentralization (Bresnahan, Brynjolfsson, and Hitt, 2002), modern perspectives on the innovative process emphasize the importance of a network of *external* information relationships (Mendelson, 2000; Gulati, 1995; Powell, Koput, and Doerr, 1996; Bradley and Nolan, 1998). For example, modern firms often obtain new product information from their customers, suppliers, partners, or new employees (Von Hippel, 1982; Saxenian, 1994). Indeed, empirical research on “information-age” organizations has shown that combinations of decentralized architectures and external information awareness characterize many modern firms competing in industries with faster product cycles (Mendelson, 2000). Thus, it is likely that a firm’s ability to promote cross-boundary information flows is a key determinant of the advantages it can derive from upgrading its internal information processing systems.

Because of the difficulty in observing organizational assets within firms, however, there has been little empirical research focused on identification of organizational complements beyond decentralization. This paper tests the hypothesis that in addition to decentralization, external focus is an important complement to IT investment 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 information, and that the central mechanism through which this system of complements is associated with greater productivity is through product leadership. The implication is that organizations that do not have the appropriate mechanisms in place to capture environmental information will not experience the same productivity increases from their IT expenditures, even if they have decentralized their decision making processes.

Identifying these hidden organizational assets is important for several reasons. Although the academic literature has established a strong connection between IT expenditures and productivity, there is significant interest in why some firms seem to derive greater benefits from IT investments than others. A central hypothesis is that the excess returns observed in these firms result from the unobservability of some correlated assets such as organizational complements (Dedrick, Kraemer and Gurbaxani, 2003). Identifying these organizational complements, therefore, has direct implications for the management of IT resources. Furthermore, identification of complementarities between IT investment and external focus has implications for other managerial choices, such as where firms locate. Scholars have argued that some geographic areas, such as the Silicon Valley, are characterized by a much more open flow of information among firms (Saxenian, 1994). Therefore, our results may help explain why firms in these regions have experienced unusually high rates of innovation and productivity during the IT revolution. Similarly, researchers have argued that much of the variation in IT-related growth observed at the cross-country level results from differences in organizational form found among firms located in different countries (Dewan and Kraemer, 2000; Bloom, Sadun, and Van Reenen, 2007; Bloom, Sadun, and Van Reenen, 2008). Therefore, policy makers may also benefit from understanding how IT returns are impacted by the prevalence of particular organizational structures.

To test the hypothesis that a firm’s external information practices are an important determinant of IT returns, we use data from several sources. Our organizational data is collected from a primary survey administered to over 250 firms in 2001. In addition to questions related to workplace organization, our survey includes questions about firms’ external information practices, such as whether firms regularly use competitive benchmarking and whether employees from suppliers or partners are commonly included on project teams. The measurement and incorporation of these external constructs into IT demand and productivity analyses is the key contribution of this paper. However, an additional contribution of our study is that our survey includes direct measures of product cycle speed. Therefore, in addition to testing how these organizational practices affect productivity, the availability of product

cycle information allows us to test the mechanism, hypothesized in this and earlier studies, through which this system of complements affects productivity. In particular, 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 also combine the cross-sectional survey data with longitudinal data on firms' production and IT inputs, following earlier research that treats organizational practices as relatively fixed in short panels (Bresnahan, Brynjolfsson and Hitt, 2002). This assumption, supported by case literature documenting the high adjustment costs associated with organizational change, allows us to test how differences in organizational architectures impact the productivity of IT investments using both cross-sectional and longitudinal variation in IT investment levels.

Our findings suggest that 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 that these assets are associated with faster product cycles, suggesting that firms with this system of practices in place are able to more rapidly innovate, develop, and deliver new products to market. Furthermore, our productivity estimates indicate that the most productive firms jointly adopt information technologies along with practices that promote decentralization and external focus. After accounting for these organizational factors, the main effect estimate on IT is no longer significant in our regression estimates, suggesting that some of the excess returns to IT observed in earlier studies may have been reflecting the presence of these organizational assets. The story suggested by our findings is that exogenous price declines in IT lower the costs of internal information processing, but firms are only able to effectively leverage these improvements by absorbing and responding 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

Researchers have suggested that as with other general purpose technologies, the value of information technology investments is magnified by organizational co-invention (David, 1990; Bresnahan and Trajtenberg, 1995), a theme with a long history in research on the organizational impact of information systems (Attewell and Rule, 1984; Zuboff, 1988). A substantial empirical literature has since emerged that uses micro-data to identify the impact of these "organizational complements" on information technology investments. Because information technologies lower information costs within the firm, much of this literature has focused on the decentralization of information and decision-making authority within the firm and higher levels of human capital that accompany IT investments. Bresnahan, Brynjolfsson and Hitt use information on the use of team-based production to show that the adoption of these practices in combination with information technologies leads to productivity benefits (Bresnahan, Brynjolfsson, and Hitt, 2002). Caroli and Van Reenen make a similar argument, using data on the decentralization of decision-making authority in a sample of British and French establishments (Caroli and Van Reenen, 2002). Brynjolfsson, Hitt and Yang include organizational variables 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). Related research also finds that nine out of every ten dollars of market value associated with IT investments can be attributed to organizational investment (Brynjolfsson and Yang, 1999).

Many of these studies have hypothesized that the mechanism through which decentralized authority, information technologies, and higher skilled workers affects productivity is through product variety and customization. By using information technologies and associated practices to increase efficiency, lower setup times, and move authority to line workers, firms have been able to use customized production to support new business strategies. Indeed, at the beginning of the so called "productivity paradox", a central hypothesis was that the benefits of computing were not showing up in the output statistics because they were primarily improving product variety which is poorly captured in economy-wide productivity statistics (Brynjolfsson, 1994). More recently, however, researchers have been able to use micro-data to directly test the hypothesis that information technologies affect product customization. For

example, Brynjolfsson and colleagues associate Internet commerce with greater product variety (Brynjolfsson, Hu, and Smith, 2003). Gao and Hitt used trademark data to show that firms that use information technology tend to offer a wider array of products (Gao and Hitt, 2004). Bartel and colleagues use plant-level data from valve-manufacturing to show that plants that use information technologies are more likely to move to customized production (Bartel, Ichniowski, and Shaw, 2008).

However, although most of the literature on organizational complements has focused on the firm's internal organization, much of the product innovation and development process in modern firms is governed by external networks. Collaborating firms often receive product ideas through customers, suppliers, or partners, leading many researchers to focus on the network, rather than the firm, as the more important locus of innovation (Powell, Koput and Doerr, 1996; Tsai, 2001). Indeed, modern companies engage in significant network collaboration at all stages of the product development process. Researchers have suggested new market access and speed of product introduction as two of the key reasons that firms collaborate (Hagedoorn, 1993; Eisenhardt and Schoonhoven, 1996). From a theoretical perspective, the transition to the networked organizational form signifies a greater flow of information across firm boundaries, and a subsequent rise in the need for information processing capacity within the firm. These arguments are consistent with the information processing view, which considers the organization as an information processing system that responds to environmental signals (Radner, 1993; Galbraith, 1973). From this perspective, organizations collect information from their environments, process this information, and choose the most effective response.

This body of work suggests that the information processing benefits of information technologies, and therefore the productive returns to IT investments, may be substantially affected not only by how the firm processes information internally, but also by how it interacts with external network actors. Put simply, increasing the firm's internal information capacity requires new sources of information in order for these changes to be productive. Despite the likely complementarities between a firm's internal and external information practices, however, there has been little empirical research focused on how external information practices might affect the productivity of a firm's IT investments.

There are, however, a number of studies that connect IT to greater external focus in the case and academic literatures. Scholars have examined specific ways in which information technologies make it less costly for firms to acquire outside information. For example, computers allow firms to coordinate information across supply chains (Cachon and Fisher, 2000). Computers also allow firms to exchange information about goods and services with customers, promoting user innovation. Von Hippel describes how the widespread availability of design software has moved the locus of innovation for the kite-surfing industry away from firms and towards users (Von Hippel, 2005). Computers have also opened up labor markets, increasing firms' use of contingent labor as well as the incidence of job-hopping across firms, leading to a greater flow of human capital across firm boundaries (Cappelli, 1993). None of these studies, however, explicitly looks at a firm's external information practices in the context of organizational complements to IT investment.

In the set of papers that is perhaps closest to ours, Mendelson and Pillai combine several perspectives from the information processing literature in their conceptualization of the "information-age organization". Using evidence from the computer industry, they find evidence that "information-age organizations" effectively combine internal workplace reorganization, external information awareness, and activity focus (Mendelson and Pillai, 1998; Mendelson, 2000). They also find that these effects are especially pronounced when firms face external environments characterized by rapid product cycles and technological change. These studies do not explicitly investigate the potential contribution of these information practices to the productivity of a firm's IT investments, and their data set is limited to the computer industry. However, their findings provide significant support for the idea that external information practices, decentralized decisions, and information technologies form part of a reinforcing cluster that defines modern firms. In this paper, we focus on testing this hypothesis in the context of the productivity of IT investments. In the next section, we describe the data we use to test this hypothesis.

Data and Measures

Our organizational practice data are drawn from a primary survey administered to 253 senior human resource managers in 2001. The questions were primarily drawn from prior surveys on workplace organization, and extend a previous wave of surveys on IT usage and workplace organization administered in 1995-1996 (Bresnahan,

Brynjolfsson, and Hitt, 2002). The survey also incorporates additional questions on internal and external information practices motivated by recent research on IT and organizational design (Mendelson and Pillai, 1998). It 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 other production inputs from other sources. We describe the construction of our measures below.

Table 1: Organizational Practice and Human Capital Survey Variables

| Variable | Variable | Range | N | Mean | Std. Dev. |
|--|-----------------|-------|-----|--------|-----------|
| <u>External Focus</u> | | | | | |
| We regularly use competitive benchmarks | <i>BENCH</i> | 1-5 | 233 | 3.58 | 1.06 |
| Project teams include suppliers, partners, customers | <i>PROJTEAM</i> | 1-5 | 227 | 2.21 | 1.10 |
| Executives spend significant time recruiting | <i>EXECRCRT</i> | 1-5 | 247 | 2.15 | 0.82 |
| <u>Internal Organization</u> | | | | | |
| Self-managing teams | <i>SMTEAM</i> | 1-5 | 249 | 2.39 | 1.15 |
| Cross-training | <i>XTRAIN</i> | 1-5 | 250 | 3.29 | 0.98 |
| Team-building activities | <i>TEAMBLD</i> | 1-5 | 249 | 2.70 | 1.04 |
| Quality circles | <i>QUALCIRC</i> | 1-5 | 243 | 2.51 | 1.17 |
| Promotion based on teamwork | <i>PROMTEAM</i> | 1-5 | 245 | 2.38 | 1.14 |
| Who decides pace of work (5=employees) | <i>PACE</i> | 1-5 | 252 | 2.48 | 0.75 |
| Who decides method of work (5=employees) | <i>METHOD</i> | 1-5 | 251 | 2.78 | 0.83 |
| <u>Product Cycles and New Technology Adoption</u> | | | | | |
| Typically first to introduce new products | <i>INNOV</i> | 1-5 | 218 | 3.22 | 1.08 |
| Leading edge adopter of new technologies | <i>ADOPT</i> | 1-5 | 225 | 3.10 | 1.09 |
| Weed out marginal product lines | <i>MARG</i> | 1-5 | 208 | 3.34 | 0.99 |
| <u>Education</u> | | | | | |
| Less than high school | <i>%LHS</i> | 0-80 | 209 | 9.42% | 15.23% |
| High school degree | <i>%HSED</i> | 0-100 | 212 | 46.33% | 27.58% |
| Some college | <i>%SCED</i> | 0-100 | 205 | 20.08% | 16.18% |
| 4 Year college degree | <i>%COLL</i> | 0-90 | 206 | 20.22% | 19.97% |
| Advanced degree | <i>%ADDEG</i> | 0-50 | 200 | 5.78% | 8.46% |
| <u>Occupational Mix</u> | | | | | |
| Clerical | <i>%CL</i> | 0-70 | 229 | 12.63% | 12.14% |
| Unskilled Blue-Collar | <i>%US</i> | 0-90 | 224 | 22.85% | 24.94% |
| Skilled Blue-Collar | <i>%SK</i> | 0-88 | 227 | 23.60% | 20.45% |
| Managers and Supervisors | <i>%MG</i> | 0-65 | 230 | 17.75% | 9.96% |
| Professionals | <i>%PF</i> | 0-79 | 227 | 22.63% | 18.56% |

Workplace Organization

Our internal workplace organization variable is based upon a measure used in a number of earlier studies, and shown to have reliable properties (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*).

We also include two additional measures related to the allocation of decision authority among workers. The first of these indicates who determines the pace of work (*PACE*) and the second indicates the methods used in 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.

$$WO = \text{STD}(\text{STD}(\text{SMTEAM}) + \text{STD}(\text{TEAMBLD}) + \text{STD}(\text{PROMTEAM}) + \text{STD}(\text{QUALCIR}) + \text{STD}(\text{PACE}) + \text{STD}(\text{METHOD}))$$

We chose this variable for several reasons. The variables in *WO* capture much of the variation across firms in workplace organization. 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 decentralizing decision-making in teams. Finally, *WO* as a concept of workplace organization is relatively narrow and specific, making our model and econometrics more precise and interpretable, although *WO* is probably not catching all of the relevant internal organizational changes. 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 the dynamics of *WO* are reasonably clear. It is likely that many of the firms were in the process of adopting these practices during the sample period. Work organization is hard to change but has nevertheless been changing toward the set of practices we label *WO*.

External Focus

External focus was measured using survey responses to questions about external information practices. To construct our external information measure, we focused on three key measures. Competitive benchmarking (*BENCH*) indicates the firm's cognizance of the practices and performance of the best performers in the industry, and is a common measure of external information awareness in related 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 a part of project teams (*PROJTEAM*). Finally, the flow of human capital among firms is another way in which firms access information about new products and technologies, especially in industries characterized by high levels of human capital, quickly changing skills and fast product cycles (Saxenian, 1994). We measured the firm's emphasis on recruiting by asking whether executives dedicated significant time to recruiting (*EXECRCRT*). The full form of our external focus variable is shown below.

$$EXT = \text{STD}(\text{STD}(\text{BENCH}) + \text{STD}(\text{PROJTEAM}) + \text{STD}(\text{EXECRCRT}))$$

The measurement and incorporation of this construct into IT demand and productivity analysis is a key contribution of this analysis. 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 a measure of external focus with a zero mean and a standard error of one.

Product Cycles, Innovation, and Technological Change

Our hypothesis is that external focus affects productivity through product leadership. One advantage of our survey data is that it includes information on firm's product cycle behavior, allowing us to directly test this relationship. We construct two variables, one to measure a firm's overall product leadership, and another to measure the speed of internal product development. Although overall product leadership should be closely related to the firm's innovative capabilities, product development speed should primarily be affected by the internal organization of firms. Our overall product leadership variable (*PRODCYCLE*) combines measures of whether

- 1) the firm is usually among the first in its industry to introduce new products, and
- 2) if they regularly weed marginal products out of their product lines.

We also measure the speed of a firm's internal product development processes, measured by how long relative to its competitors firms take to introduce a new product or service once it has been approved (*PRODSPEED*). Both of these measures were standardized to have a zero mean and standard deviation of one.

Value Added and Non-IT Production Inputs

Panel data on capital, labor, and value-added were obtained for the firms in our sample through 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 2 shows statistics for the 2001 cross section of the Compustat variables included in our analysis.

Table 2: Production Function Variables

| | Variable | N | Mean | Std. Dev. |
|----------------------------------|-----------------|----------|-------------|------------------|
| <u>Production Inputs</u>* | | | | |
| Log(Sales) | <i>LSALES</i> | 177 | 6.80 | 1.77 |
| Log(Value Added) | <i>LVA</i> | 177 | 5.73 | 1.80 |
| Log(Employment) | <i>LEMPLOY</i> | 177 | 8.44 | 1.66 |
| Log(Capital) | <i>LCAP</i> | 177 | 6.01 | 2.02 |

*Source: Compustat, 2001 Cross-section

Computerization

Our survey data includes two measures of computerization that can be compared to other organizational variables in the 2001 cross-section. 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*). These internal measures, however, are only available in the survey base year. Therefore, to construct our panel data, we use longitudinal IT measures based on a new data set describing firm-level IT employment over the last two decades. We use these firm-level IT employment measures as a proxy for firms aggregate IT expenditures. Although aggregate firm-level IT expenditure data has been used in some recent studies, 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 Computer Intelligence Technology Database (CITDB) capital stock data or our employment data, although imperfect measures of total IT expenditure, are generally available for much longer time periods, and therefore form the basis of most large scale econometric studies of IT productivity.

The IT employment data set, the measure construction, and their sampling properties are described in greater detail elsewhere (Tambe and Hitt, 2008). 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 CITDB capital stock data, in several ways. Although much recent research on IT productivity has increasingly relied on the CITDB, the main panel of these data is 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.¹ Because the CITDB capital stock data are reliably available only through 2000, a panel around a post-2000 base year cannot be constructed. Our employment based data, by contrast, are reliably available through 2006.

Furthermore, because our employment data are available for a much larger sample of firms than the capital stock data including non Fortune-1000 firms, they triple the number of firms in the survey for which IT measures and organizational practice data are jointly available. Finally, 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.² Using this data set, we construct measures of the total number of IT workers in a given firm-year (*%IT EMP*), 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 3. The mean usage of both PC's 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 about 30% of workers used email. The average firm in our sample had about 470 IT workers in 2001, comprising slightly over 2% of the total employment in these firms. A large standard deviation for all of these measures suggests that some firms, such as those in IT-producing industries, have much greater IT usage than others. Therefore, we log transform these IT measures to facilitate linear comparisons with our organizational factor data.

Table 3: IT Variables

| | Variable | N | Mean | Std. Dev. | 1 | 2 | 3 |
|--|-----------------|----------|-------------|------------------|----------|----------|----------|
| 1. % IT Employees* | <i>%IT EMP</i> | 177 | 2.3 | .23 | 1 | | |
| 2. % PC Users [†] | <i>%GPC</i> | 171 | 63.7 | 29.9 | .23 | 1 | |
| 3. % Email Users [†] | <i>%EMAIL</i> | 171 | 61.3 | 30.4 | .21 | .85 | 1 |
| *From Tambe and Hitt (2008) [†] Author's Survey. Correlations are shown using logged variables. | | | | | | | |

Methods

Access to both cross-sectional organizational and innovation data, as well as to panel data on IT and other production inputs allows us to test the implications of our complementarities hypothesis in a number of ways. We describe them 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 inputs are complements, price declines in IT should lead to greater use of all complementary inputs.

Product Cycle Regressions

Our central argument is that demand for these inputs co-varies because using them together leads to greater productivity. However, before directly testing their impact on productivity, we can use our cross-sectional survey

¹ 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.

²Correlations between our employment data set and other well known data sets, such as the CITDB, ComputerWorld, and InformationWeek data sets are generally above .5 (Tambe and Hitt, 2008).

data to develop some insight into how these inputs affect firm productivity. We argue that external focus is part of a cluster of practices that affect productivity through innovation and product mix. Therefore, we should find that firms with these organizational practices are more likely to exercise product leadership. To test these relationships, we embed them in a simple regression of the form

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

where PROD can represent either of our two product measures, WO is decentralization, EXT is external focus, and IT is IT usage within the firm. For our IT usage variable, we report results using both the percentage of workers who use email, as well as the percentage of a firm's employees who are IT workers. Results using percentage of PC users were similar to those using percentage of email users, and were therefore omitted.

Productivity Regressions

Finally, we can test our main hypothesis, which is that if workplace organization, external focus, and information technology are complements, they should be most productive when adopted together as a system. We test this proposition by embedding our measures within a production model, a framework which has been widely used in IT productivity research (Stiroh, 2004 reviews much of this literature). For example, in IT productivity research, 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 in research testing for the presence of complementarities between IT and organization (Bresnahan, Brynjolfsson and Hitt, 2002). Our primary 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 is 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 fixed in the 4-5 year time span surrounding 2001. This type of construction, in which organizational factors are held fixed in short panels, has been used in prior research (Bresnahan, Brynjolfsson, and Hitt, 2002), and the assumption that organizational factors are associated with high adjustment costs and take considerable time to change is supported by substantial case and econometric evidence (Applegate, Cash and Mills, 1988; Attewell and Rule, 1984; Davenport and Short, 1990; David, 1990; Malone and Rockart, 1991; Milgrom and Roberts, 1990; Murnane, Levy and Autor, 1999; Morton, 1991; Zuboff, 1988; Bresnahan and Greenstein, 1997; Brynjolfsson and Hitt, 1997).

One drawback of this construction is that we cannot test the impact of changes in these organizational factors while holding firm factors fixed. Our regression estimates, therefore, 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.

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, along with 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 measure of external focus is correlated with all of our IT measures, and in fact, is more highly correlated with our IT measures than our workplace organization variable. 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 above .50 ($p < .01$), indicating that external information practices are significantly more likely to appear in firms with decentralized decision architectures. These correlations support the idea that external focus, workplace organization, and information technology usage are likely to be found together in firms.

Table 4: Correlations Between IT Measures and Work Practices

| | LITINT | %EMAIL | % GPC | WO |
|---|--------|--------|-------|-------|
| External Focus (EXT) | .20** | .21** | .21** | .50** |
| Decentralization (WO) | .11 | .33** | .25** | |
| Partial correlations controlling for industry, % clerical workers, and % blue-collar workers N=160-210, due to non-response ** $p < .01$, test is against the null hypothesis that the correlation is zero | | | | |

Product Cycle Measures

Our central argument is that the demand for these inputs co-varies because when used together, they enable firms to be more productive. In particular, scholars have argued that this system allows firms to be more productive by enabling greater product variety and customization. We use our cross-sectional survey data to provide support for the idea that along with information technologies, external focus and workplace organization are an important part of the product variety story.

Table 5 shows associations between product cycle measures and our technology and organizational variables. In Columns (1) and (2), the dependent variable is the firm's product leadership, measured by 1) whether the firm is usually the first in its industry to introduce a new product, and 2) how likely it is to weed out marginal products. Our estimates from both Column (1) and Column (2) indicate that these measures of product leadership are most closely associated with external focus. This is consistent with the view that firms in environments characterized by more rapid product change require external "sensors" through which they can capture environmental signals. The dependent variable in Column (3) and Column (4) 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, the measure captures speed of execution, rather than access to new ideas. The estimates in Column (3), using the survey based email measure, indicate that technology usage is significantly related to rapid internal product development. The point estimate on information technology in Column (4) is positive, but not significant. The point estimate on workplace organization is positive in both (3) and (4), although perhaps due to our sample size, is not significant in either model. In total, the results from this table suggest that although the ability to exhibit product leadership is more closely connected to a firm's ability to capture ideas from other actors in its network, its ability to "process" these signals in a timely manner is governed by its internal information processing capacity. In quickly changing environments, firms require both external and internal information processing capabilities to process external information and mount an effective response.

Table 5: OLS Regressions relating Product Cycle Measures to Technological and Organizational Measures

| | Product Leadership | Product Leadership | Internal Dev Speed | Internal Dev Speed |
|------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| | (1) | (2) | (3) | (4) |
| External Focus (EXT) | .189 (.083)** | .208 (.085)** | .039 (.089) | .059 (.090) |
| Decentralization (WO) | .190 (.086)** | .196 (.085)** | .093 (.092) | .133 (.090) |
| Log(% Email) | .043 (.103) | | .219 (.111)** | |
| Log(% IT Employ) | | .033 (.036) | | .021 (.037) |
| Controls | Industry | Industry | Industry | Industry |
| R² | .19 | .19 | .15 | .15 |
| N | 149 | 151 | 149 | 151 |
| ** p<.05, *p<.10 | | | | |

Productivity Regressions

The central hypothesis of this paper is that external focus is an organizational asset that affects the returns to IT investment, especially when combined with effective internal workplace organization. Table 6 shows the results from regressions testing this hypothesis. All estimates are from pooled OLS regressions, and standard errors are clustered by firm.

First, we establish a baseline estimate of the contribution of IT to productivity during our 1998-2006 panel. The coefficient estimate on IT is about .070 ($t=2.09$), consistent with many of the pooled OLS regressions of this type that appear in the literature. In Column (2), we include only decentralization measures for comparison with earlier studies. Although the coefficient estimate on decentralization is positive and significant, the IT interaction term is not, perhaps because variation in our IT measure is more likely to reflect firms that have moved beyond the use of computers for internal communication. The coefficient estimate on IT drops slightly, but is close in magnitude 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 significant, indicating that for these data, external focus may in fact be a slightly better indicator of firms having made the necessary organizational investments. In our main results, reported in Column (4), we include the full set of organizational factors and interaction terms. Interestingly, 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. The estimates suggest that doubling IT investment raises productivity by about 8%, but only for firms that are one standard deviation above the mean according to our organizational factor measures.

One of the concerns with these estimates is that because we cannot perform fixed-effects tests, unobserved firm factors may be biasing upwards the returns to our interaction terms. In particular, a primary concern is that these organizational changes may be accompanied by changes to the firm's human capital and skills, which have also been shown to be complementary to technology adoption (Bresnahan, Brynjolfsson and Hitt, 2002). Fortunately, our survey data also include measures of the firm's human capital, so we can directly address this concern in our regression model. Column (5) is our most robust specification, which includes controls for education and workforce composition 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.

These results suggest that in modern firms the system of complements that includes decentralization, external focus, and IT intensity is more closely associated with productivity than IT in isolation. IT is positively and significantly associated with productivity, but only for those firms through investment or luck, have the right organizational

structures in place. In part, our study suggests that some of the excess returns to IT investment that appeared in earlier studies may have reflected the presence of these organizational assets. While prior work has already shown the importance of workplace decentralization, 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.

Table 6: Productivity Regressions

| DV: Log(Value Added) | 1998-2006 | 1998-2006 | 1998-2006 | 1998-2006 | 1998-2006 |
|--|-------------------|-------------------|-------------------|-------------------|---|
| | (1) | (2) | (3) | (4) | (5) |
| Log(IT Employment) | .075 (.036)** | .071 (.037)* | .074 (.036) | .034 (.035) | .019 (.035) |
| Log(Non-IT Employment) | .588 (.051)** | .599 (.048)** | .579 (.052) | .622 (.045)** | .642 (.050)** |
| Log(Capital) | .318 (.028)** | .297 (.027)** | .318 (.028) | .302 (.027)** | .299 (.033)** |
| WO | | .258 (.148)* | | .243 (.128)* | .097 (.132) |
| EXT | | | .072 (.154)** | -.128 (.149) | -.276 (.148) |
| WO x EXT | | | | .392 (.118)** | .326 (.126)** |
| WO x IT | | .038 (.033) | | .035 (.029) | .003 (.030) |
| EXT x IT | | | .005 (.035) | -.029 (.036) | -.065 (.035) |
| WO x EXT x IT | | | | .085 (.031)** | .071 (.033)** |
| Controls | Industry, Year | Industry, Year | Industry, Year | Industry, Year | Industry, Year, %Skilled, %Professionals |
| R ² | .93 | .93 | .93 | .93 | .93 |
| N | 1094 | 1094 | 1094 | 1094 | 867 |
| <p>*p<.1, **p<.05, ***p<.01, test is against the null hypothesis that the correlation is zero Huber-white robust standard errors are shown in parentheses IT Employment, Non-IT Employment and Capital are entered in logs. Dependent variable in all regressions is log(Value Added)</p> | | | | | |

Conclusion

We provided evidence that external focus, a firm's awareness of information in its environment, is an important determinant of the returns to its information technology investments. We hypothesized that decentralized firms are more productive because they are capable of processing more external information. Therefore, external sensors are required to reap the full benefits of information technology investments. Our findings in this study support this hypothesis. 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 rapid product development, supporting the idea that product development is a primary mechanism, hypothesized in several IT value studies, through which external focus is likely to affect productivity. We also find evidence of complementarities in the production function--IT, decentralization, and external focus are 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 entire system of technological and organizational resources. Our findings indicate that some of the excess return implied by earlier IT value assets may be explained in part by these "hidden" organizational assets.

From a research perspective, our study primarily 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 individual 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 wide variation in returns to IT investments that have been observed among firms, as well as cross-country differences in returns to IT adoption, may be due to the growing importance of networks in production (Dewan and Kraemer, 2000; Van Reenen, Sadun, and Bloom, 2008). For instance, the degree to which firms, suppliers, and customers in an economy are “networked” may differ substantially among countries and even among regions within the same country (Saxenian, 1994). Our study, therefore, is also related to a growing literature that explores how factors outside the firm, such as competitive environment, impact IT value (Melville, Gurbaxani, and Kraemer, 2004).

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 level of benefits (Milgrom and 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. Some of these external practices include competitive benchmarking and inter-organizational product teams. However, it is likely that our measures represent the effects of 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. High on the list of reasons for why IT investments appear to have driven different levels of productivity growth across countries is differences in organizational factors in firms in these countries. For instance, researchers have shown that decentralization is much more likely to characterize firms in some countries than in others, due to cultural differences (Van Reenen, Sadun and Bloom, 2008). Our findings suggest that the degree to which firms are networked is an additional factor that may explain differences in IT led productivity growth. Even within 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 profound.

There are, however, some limitations to this study. Because of our research design, we were unable to perform fixed effect productivity regressions to determine if within-firm changes in organizational assets drive productivity changes. However, we controlled for the primary factor, human capital, that may have influencing our estimates. Furthermore, supplementary data on the product development mechanisms through which these factors affect productivity supports the complementarities story. In the future, however, a research design which includes repeated waves of organizational surveys may be a useful extension to this research. 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 further advance this agenda.

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