THE EXTROVERTED FIRM:

HOW EXTERNAL INFORMATION PRACTICES AFFECT INNOVATION AND PRODUCTIVITY

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Abstract

We gather detailed data on organizational practices from 253 firms to examine the hypothesis that external focus – the ability of a firm to detect and therefore respond to changes in its external operating environment – increases returns to information technology, especially when combined with decentralized decision-making. First, using survey-based measures, we find that external focus is highly correlated with organizational decentralization and IT investment. Second, we find that a cluster of practices including external focus, decentralization and IT is associated with improved product innovation capabilities. Third, we develop and test a 3-way complementarities model that indicates that the combination of external focus, decentralization and IT is associated with significantly higher productivity. In our sample, firms that have only one or two of these organizational practices in place, instead of all three, are not more productive than firms with none of them. We also introduce a new set of instrumental variables representing barriers to IT-related organizational change and use these measures to show that our results are robust when we account for the potential endogeneity of organizational investments. Our results may help explain why firms that operate in more information rich environments such as high-technology clusters or areas with high worker mobility have experienced especially high returns to IT investment and suggest a set of practices that some managers may be able to use to increase their returns from IT investments.

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

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1. Introduction

Falling internal communication costs and new internal information practices enable information-age firms to quickly respond to changes in consumer preferences, competition, and technology. However, improvements to a firm's decision-making structure increase performance only if firms receive accurate and timely information about the operating environment (Mendelson and Pillai, 1999). This suggest that the adoption of practices used to detect changes in the *external* operating environment and inform decision-making should become increasingly common. Internet companies are an extreme example: firms like Amazon and Google record every customers' keystrokes and analyze the data to continuously optimize their products, processes and marketing. But off-line companies are also using customer data extensively. For example, Harrah's invested heavily in recording data on consumer gaming patterns, which they used to design compelling packages to attract high-value customers and outperform competitors (Loveman, 2003). Similarly, firms like Cisco, Capital One, UPS, and Wal-Mart have been described as gaining competitive advantage by adopting an aggressive approach to learning about their customers and competitors (Davenport and Harris, 2007).

A growing research literature on the behavior of modern organizations has looked at some of these changes in the competitive environment (Saxenian, 1996; Dyer and Singh, 1998; Dyer and Nobeoka, 2000; Powell, Koput, and Smith-Doerr, 1996; Bradley and Nolan, 1998; Von Hippel, 1998). Researchers have also emphasized the role of IT in the development of information gathering and processing capabilities that facilitate external orientation (Mendelson and Pillai, 1999; Malhotra et al., 2005; Pavlou and El Sawy, 2006; Rai et al., 2006; Bharadwaj et al., 2007). However, the growing emphasis on external orientation has not been integrated into the IT productivity literature, which has primarily emphasized the importance of adopting organizational changes like decentralization in conjunction with IT investments (Bresnahan, Brynjolfsson, and Hitt, 2002; Brynjolfsson, Hitt, and Yang, 2002).

In this study, we argue that information technologies are most productive in decentralized organizations when they allow firms to quickly respond to external information. The central argument of this paper is that the combination of *external focus*, *decentralization* and *IT investments* forms a 3-way system of complements resulting in higher productivity levels (Figure 1). For example, Harrah's, in addition to adopting new information technologies to monitor consumer gaming patterns, simultaneously made extensive changes to internal practices, such as implementing the appropriate incentives for customer service personnel to keep high-value customers happy. These changes were required to successfully handle the massive amounts of customer intelligence being generated.

The implication is that organizations that do not have the appropriate receptors in place through which to sense environmental change will not experience the same returns to IT investments, even if they have decentralized. In keeping with earlier research (Mendelson and Pillai, 1999), we define "external focus" to be a set of practices firms use to detect changes in their external operating environment. Mendelson and Pillai argue that in information-rich environments, firms should engage in practices that make up-to-date, accurate information available to decision-makers. The literature has emphasized several mechanisms through which firms can capture external information, such as customer interaction, benchmarking, and using inter-organizational project teams. We argue that returns to IT and decentralization are higher in firms that have adopted these practices.

Conceptually, complementarities between external information awareness and internal information practices are grounded in the literature on information processing organizations (Radner, 1992; Cyert and March, 1973). Because 'boundedly rational' organizations are limited in the amount of information they can effectively process, improvements in internal information processing capabilities, such as those offered by information technologies, increase the firm's capacity to process information for decision-making and to therefore respond to external information. Thus, the largest productivity benefits from improving a firm's internal information-processing infrastructure should be observed in dynamic environments where firms continuously capture and respond to external signals. Beyond broad performance benefits, this literature places special emphasis on product development as an important mechanism through which IT-led improvements in information processing lead to higher productivity (Mendelson, 2000; Pavlou and El Sawy, 2006; Bartel, Ichniowski, and Shaw, 2007). Firms that effectively sense and process external information should have market-based advantages when introducing new products (Kohli and Jaworski, 1990; Mendelson and Pillai, 1999).

Our study is based on a 2001 survey of organizational practices in 253 moderate and large sized firms, matched to data on IT investment and firm performance from private and public sources. In addition to including measures of internal organization used in prior work, we included constructs to capture external focus and product innovation, motivated specifically by the work done by Mendelson and Pillai (1999) on external practices in the computer manufacturing industry, but adapted to a more heterogeneous set of firms, and broadened to include other sources of external information such as tacit knowledge obtained from the strategic recruitment of new employees. We first find that external focus, decentralized organization and IT investment are correlated. Second, we find that these practices lead to higher product innovation rates. Finally, we estimate a three-way complementarities model (IT, external focus, decentralization) and demonstrate that firms that combine all three practices derive substantially greater benefits from their IT investments. Our econometric identification strategy includes the assumption that organizational practices are quasi-fixed in the short run. However, we also introduce an innovative set of instrumental variables that captures inhibitors of organizational change to demonstrate that our results are not sensitive to this assumption. In our preferred specifications, the output elasticity of IT investment is at least 8 percentage points higher in firms that are one standard deviation above the mean on both our external focus and organizational decentralization measures compared to other firms in our sample.

These findings indicate that firms can more successfully leverage IT investments if they effectively capture external information through networks of customers, suppliers, partners, and new employees. Mounting a more effective response to 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 appear to be part of a mutually reinforcing cluster associated with faster product cycles and higher productivity.

Our paper contributes to a literature on IT value, supporting the argument that organizational complements lead to higher IT returns (Brynjolfsson and Hitt, 1995; Brynjolfsson and Hitt, 2000; Dedrick, Kraemer, and Gurbaxani, 2003; Melville, Kraemer and Gurbaxani, 2004). We build upon prior work that addresses complementarities between IT and internal practices such as decentralized decision making (Bresnahan, Brynjolfsson, and Hitt, 2002; Caroli and Van Reenen, 2002) but add the external orientation dimension which has been shown to be important in technology-intensive firms (Mendelson and Pillai, 1999; Pavlou and El Sawy, 2006). Identifying organizational complements is useful for managers who are restructuring their organizations to take advantage of improvements in computing. In addition, our results improve our understanding of why firms in information-rich environments such as Silicon Valley (Saxenian, 1996) receive greater benefits from technology investments and why IT returns may be influenced by geographic position (Dewan and Kraemer, 2000; Bloom, Sadun, and Van Reenen, 2008).

2. Data and Measures

Our organizational practice measures are generated from a survey that was administered to 253 senior human resource managers in 2001. The survey was conducted by telephone on a sample of 1,309 large and upper middle-market firms[3] that appear in a database of IT spending compiled by Harte Hanks (see further detail below) and also have the requisite financial data in Compustat. The survey yielded a response rate of 19.3% which was typical for large scale corporate surveys at the time. The sample of responding firms has a slightly higher proportion of manufacturing firms relative to the sample population (62% vs. 54%) and the firms tend to be slightly smaller when measured in sales, assets, employees and market value. However, after conditioning on industry, the size differences between responding and non-responding firms are not statistically significant. Furthermore, there is no significant difference between responding and non-responding firms in return on assets or sales per employee.

[3] The sample contains 806 Fortune 1000 firms as well as 503 firms that are present in Compustat but not Fortune 1000 that are routinely sampled by Harte-Hanks over our time period.

The questions for this survey were drawn from a previous wave of surveys on IT usage and workplace organization administered in 1995-1996, and by incorporating additional questions on external and internal information practices motivated by research on IT and organizational design (Mendelson and Pillai, 1998). Our survey also includes questions related to firms' human capital mix, including occupational and educational distributions (see Table 1 for a summary of variables and their descriptive statistics).

2.1 External Focus

Our measure of external focus is based on an industry-specific "external information" construct utilized by Mendelson and Pillai (1999) (designated as MP hereafter) which is in turn closely related to the customer-specific concept of "market orientation" defined by Narver and Slater (1990) and Jaworski and Kohli (1993) and operationalized by Kohli, Jaworski and Kumar (1993) (designated as KJK hereafter), but we broaden our measure to be applicable beyond customer-information (like MP) and to multiple industries. In Table 2, we present the components of our external focus measure along side the components used in related work. Both KJK and MP include constructs for direct customer interaction (see Table 2, KJK scale items 1-3, MP scale items 1-2), which we capture in a question related to customer participation on project teams, but we also include partners and suppliers (variable *PROJTEAM*). Our second question focuses on the use of competitive benchmarking (*BNCHMRK*) which relates to a firm's awareness of the industry and broader business environment in KJK (scale items 5, 6) and the industry-specific measure of order throughput benchmarking used in MP (scale item 3).

To these measures, we add additional constructs for incorporating new technology (scale item 3, variable *NEWTECH*) as well as measures that examine how the firm might capture external information through employee mobility – the involvement of executives in recruiting (EXECRCT) and the use of higher pay as an inducement to attract new employees (NEWEMP). The inclusion of employee mobility was motivated by work in strategic management that emphasizes this particular pathway as a means of gathering tacit knowledge related to the competitive or technological environment (Argote and Ingram, 2000; Song, Almeida, and Wu, 2003). Executive involvement in recruiting and pay for performance were identified as key components of digital strategy in a case study of Cisco Systems (Woerner, 2001). Pay for performance has also been central to numerous other studies, including recent work by Aral, Brynjolfsson and Wu (2009). In summary, we cover many of the same constructs as prior work, but adapt them to apply to a broader set of industries than the industry-specific measures in MP, and we place greater emphasis on non-customer information (in contrast to KJK) to reflect an operations rather than marketing focus that may better fit a heterogeneous cross-section of firms.

Correlations between the individual constructs are shown in Table 3. The measures are positively correlated, but not very highly correlated, and Cronbach's alpha for a five item scale constructed from the individual variables is 0.521. The relatively lower alpha value is because these external measures are multi-dimensional in the sense that just because firms do one of these activities, they do not necessarily also have do the others. This implies that firms in different industries may access environmental information in many ways, all of which may have similar economic impact. Indeed, in our main analysis, we could not reject the hypothesis that the standardized values of the five components of external focus have the same coefficients when entered into the regression individually. Consequently, we combined these measures in a similar manner to our workplace organization variables, where each factor is first standardized (STD) by removing the mean and then scaled by its standard deviation, yielding an external focus measure with a mean of zero and a standard deviation of one. The full form of our aggregate external focus variable is shown below.

$$EXT = STD(STD(BNCHMRK) + STD(NEWTECH) + STD(PROJTEAM) + STD(EXECRCRT) + STD(NEWEMP))$$

While higher values on this scale represent more channels of external information acquisition, firms that use none of these practices can still be externally focused (Type I error), although it is likely that firms that have implemented unmeasured external information practices will also rate high on our external focus scale. It is somewhat less likely that a firm that rates high on our external focus scale will know little about the external environment (Type II error). Regardless, to the extent that our construct mis-measures the true underlying external focus of some firms, measurement error is likely to bias *downwards* the estimates on our external focus variables. Results from productivity regressions using a variety of alternative external focus measure constructions, including one that omits the two variables associated with the employee mobility (thus are more comparable to MP and KJK) show similar results (available from authors on request).

2.2 Workplace Organization

To capture internal organizational processes that are complementary to external focus, we rely on a scale focused decentralized and team-oriented work practices used in prior work (Bresnahan, Brynjolfsson, and Hitt, 2003; Brynjolfsson, Hitt and Yang, 2002), which was originally motivated by the extensive literature on "high performance work systems" (Ichniowski, Kochan, Levine, Olson, and Strauss, 1996). The measure contains four constructs of group-based decentralized decision making [the use of self-managed teams in production (*SMTEAM*), the use of team-building activities (*TEAMBLD*), the use of teamwork as a promotion criterion (*PROMTEAM*), the use of quality circles or employee involvement groups (*QUALCIR*)] and two measures capturing individual decision rights [the extent to which individual workers decide the pace of work (*PACE*) and the extent to which individual workers decide methods of work (*METHOD*)]. The Cronbach's alpha for the four team-based measures is .732, and the alpha for all six measures is .671. Similar to external focus, we construct a scale (WO) from these measures using the standardized sum of the standardized values of each component. We utilized this scale because it shows significant variation across firms, it has been previously shown to be a useful summary metric IT-related work practices (Brynjolfsson and Hitt, 1997), and it has a clear economic interpretation as decentralized, team-based decision making which is relatively narrow and specific, making our model and econometrics more precise and interpretable.

2.3 Organizational Inhibitors

Some of our analyses are based on the assumption that the organizational measures described above are quasi-fixed over short time periods, which is theoretically justified by a large literature on organizational adjustment costs (Applegate, Cash, and Mills, 1988; Attewell and Rule, 1984; David, 1990; Milgrom and Roberts, 1990; Murnane, Levy, and Autor, 1999; Zuboff, 1988; Bresnahan and Greenstein, 1996).

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 values of the individual inhibitors. Cronbach's Alpha for the eight individual inhibitors is 0.745.

These organizational inhibitors are suitable as instrumental variables because they reflect the costs faced by firms in adopting new organizational practices. Firms that face constraints in terms of culture, work rules, or staff mix may find it more difficult or costly to reengineer existing practices, or to adopt practices complementary to new IT investments. Therefore, these organizational inhibitors are a source of exogenous variation in the degree to which we are likely to observe the adoption of organizational practices when firms adopt IT. These inhibitors, however, are less likely to be correlated with firm performance.

2.4 Product Cycles, Innovation, and Technological Change

Three of the variables from our survey data reflect a firm's product development capabilities with respect to its competitors. Our goal in choosing these measures is not to fully characterize a firm's product development processes – the literature on product development is very large and includes a variety of perspectives on effective product development (Ulrich and Krishnan, 2001). Instead, our product development variables were chosen to reflect different aspects of the product development process in which access to information might prove beneficial. We measure 1) whether a firm is normally the first to introduce a new product in its industry (*FIRST*), 2) the speed of internal product development once a new product has been approved (*SPEED*) and 3) whether a firm regularly weeds out marginal products (*PLMGMT*), and is a measure of the effectiveness of a firm's product line management. Access to different product development variables is useful because introduction of new products is related to innovation and the firm's ability to collect and process external information, but product development speed should be more closely associated with the ability to process information within the organization. Our product development measures are standardized to have a zero mean and standard deviation of one.

2.5 Information Technology

Our survey data includes two types of measures of computerization, one from our survey and one constructed from a separate data set on IT employment. Managers responding to our survey 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 from 1987 to 2006, which we use as a proxy for firms' aggregate IT expenditures.

IT employment in this data set is estimated using the employment history data from a very large sample of US-based information technology workers. Table 4 shows the occupational composition of these IT workers. These data include fewer programmers and higher numbers of support personnel. For our purposes, this employment-based data set compares favorably to alternative archival data sets, such as the Harte-Hanks CITDB capital stock data, in several ways. Although recent research on IT productivity has relied on the Computer Intelligence Technology Database (CITDB), complete panel data is generally only available for 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. Consequently, even using methods to infer capital stock from available data only yield self-consistent capital stock measures through about 2000.[4] Our employment-based data, by contrast, are available on a consistent basis through

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[4] 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

2006 and include matches for nearly all the firms we surveyed. We have benchmarked these data against a number of other sources of IT data from ComputerWorld, Computer Intelligence, and InformationWeek and generally find high correlations between these different sources in both cross-section and time series.

Descriptive statistics and correlations for the IT employment measures and the survey-based IT measures are shown in Table 5. 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-year 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 Bureau of Labor Statistics 2001 Occupational Employment Survey.[6] 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 direct comparisons with our organizational factor data. Where we require normalized measures for size, we compute IT workers as a proportion of total workers.

2.6 Value Added and Non-IT Production Inputs

We obtained longitudinal data on capital, labor, research & development expense, and value-added for the firms in our sample by using the Compustat database. We used standard methods from the micro-productivity literature to create our variables of interest from the underlying data. 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 6 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 in sales and 15,200 employees.

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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.

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

3. Methods

Providing direct evidence of complementarities is challenging due to the endogeneity of organizational practices in observational data (Athey and Stern, 1998; Brynjolfsson and Milgrom, 2009; Cassiman and Veugelers, 2006). Moreover, lack of information about the costs and value of specific organizational practices limits the ability to implement structural models of organizational investment. The existing empirical literature on organizational complements has therefore focused instead on providing evidence of the economic *implications* of complementarities between organizational practices (Arora and Gambardella, 1990; Bresnahan, Brynjolfsson and Hitt, 2002). The empirical strategy followed in these studies is to marshal a number of different types of evidence consistent with the complementarities hypothesis, which when considered in whole, strongly suggest complementarities between organizational practices.

In particular, complementarities imply that we should observe 1) the clustering of practices across firms and 2) that the simultaneous presence of these complements impacts performance more than the sum of the individual effects. We measure clustering as correlation, and performance by regression models with interactions as well as newer tests proposed by Brynjolfsson and Milgrom (2009) that contrast performance for different combinations of complementary practices. We also include two useful measurement innovations. First, unobserved human capital among firms is likely to be a significant omitted variable in prior work on organizational practices. Using our workforce data we are able to include human capital controls at the firm level. Second, we are able to consider the potential endogeneity of work practices by instrumenting these measures with our data on inhibitors to organizational innovation which indirectly capture the cost variation of organizational investments across 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 and endogeneity can play in the analysis relative to many earlier studies on organizational complementarities.

3.1 Correlation Tests

The first test we conduct is based on correlations among these organizational practices. Using our cross-sectional data, we examine how the use of IT and the proposed complementary practices co-vary in the survey base year. If these practices are complements, price declines in IT should be accompanied by greater use of both complementary organizational practices.

3.2 Product Development Regressions

We can also use our data to develop some insight into *how* these inputs affect the productivity of firms. We test how our organizational and IT variables are associated with 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 *PLMGMT*), *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 use instrumental variables to conduct regressions in which the organizational measures (*WO* 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 the location of a firm's corporate headquarters, which may affect a firm's cost for external information gathering.

3.3 Productivity Tests

We test complementarities in production by embedding our measures within a production function. The productivity framework has been widely used in IT productivity research (Stiroh, 2004 reviews much of this literature). 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 forms, has the 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, 1995, 1996; Dewan and Min, 1997), and has been used extensively in research testing for complementarities between IT and organization (Bresnahan, Brynjolfsson, and Hitt, 2002; Brynjolfsson, Hitt, and Yang, 2002). Our primary regression model can be written

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

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 to rule out some alternative explanations for our principal results.

Although our data on IT and other production inputs are longitudinal, our organizational factors data are based on a single survey conducted in 2001. We construct a seven-year panel (1999-2006) by making the assumption that organizational factors are quasi-fixed in the short run. Our survey was administered in 2001, towards the middle of our panel. Similar assumptions regarding the quasi-fixed nature of organizational assets have been used in prior research on organizational factors (Bresnahan, Brynjolfsson, and 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 cited earlier. Furthermore, in our analysis, we use adjustment cost data as instrumental variables to directly test this assumption.

An additional potentially important source of endogeneity is our IT measures. Unobserved productivity shocks will tend to exert an upward bias on the IT estimates as firms adjust IT to accommodate higher production levels. However, the endogeneity of IT investment may not exert too large an influence on our key estimates for two reasons. First, in other work we show that using GMM-based estimators that account for the endogeneity of IT investment (such as the Levinsohn-Petrin estimator) lowers our IT estimates by no more than 10% when using these data (citation obscured). Second, our key estimates, based on the 3-way complementarity between IT, external focus, and decentralization are less subject to bias relative to our main effects IT estimate because any biases that affect the complementarity term must be present only at the confluence of all three of these factors.[7] Thus, although we cannot eliminate these biases, their effects on our key estimates may be limited.

4. Results

4.1 Correlation Tests

Table 7 shows partial correlations between our IT measures and our organizational practice variables. All correlations control for firm size. We also control for 1-digit NAICS industry, as well as the percent of skilled blue-collar workers and the percent of professional workers to control for the nature of the firm's production process. Although these correlations by themselves are neither necessary nor sufficient evidence of complementarities (Athey and Stern, 1998; Brynjolfsson and Milgrom, 2009), they provide preliminary evidence as to whether managers perceive these practices as mutually beneficial.

Our external focus measure is correlated with our IT measure, and is highly correlated with the decentralization measure. Workplace organization is also positively associated with our IT measures. The correlation between workplace organization and external focus is 0.45 ($p<.01$), indicating that external information practices are significantly more likely to be found in firms with decentralized decision architectures. These correlations between external focus, workplace organization, and IT support the argument that external focus, workplace organization, and information technology usage are complements

[7] We thank an anonymous editor for making this observation.

in the production process. Furthermore, 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 either of these systems of work practices, as theory would predict.

4.2 Product Cycle Regressions

Table 8 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 are related to product development. In (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 (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 *per se*. The estimates in (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 (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 closely related to how well a firm manages 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 8, 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, these results indicate that the ability to exercise product leadership is more closely connected to a firm's ability to capture information from its environment, but its ability to internally process and manage products in a timely manner is governed by its internal information processing capacity. Competing in quickly-changing product environments, therefore, requires external receptors in addition to decentralization and technology.

4.3 Full-Sample Regression-Based Productivity Tests

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 9 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 1999 to 2006. The coefficient estimate on our IT employment 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 (e.g., Brynjolfsson and 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 decentralized work practices have more broadly diffused to all firms that can benefit from them, leading to minimal marginal effects on productivity in recent data.[8] 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

[8] Estimates from supplementary regressions (not shown) indicate that this complementarity reappears when restricting our estimates to earlier time periods.

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 0.07 to 0.08, our Column (4) estimates suggest that these benefits are only captured by firms that are above average with respect to both decentralization and external focus.[9]

To gauge the robustness of these results, we first re-estimate our model (Column 5) including a control for workforce composition (percentage of skilled workers and professionals out of total employment) to account for the fact that human capital is closely related to organizational innovation and technology adoption (Bartel and Lichtenberg, 1987). Our coefficient estimates do not change substantively after including these human capital measures. Second, we conduct instrumental variables regressions using our organizational inhibitors measures as instruments for external focus, decentralization and the interaction terms. These IV estimates (Column 6) are similar to those in earlier regressions and indicate that our results are unlikely to be driven by endogeneity of organizational investments. At the bottom of Column (6), we report values of the Hansen J-statistic, which tests the instrument 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.

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[9] We also estimated similar regressions where each of the individual external focus variables are tested individually, and where the external focus variable is constructed from different combinations of the individual external focus constructs. The results from these regressions indicate that our external focus measure is not overly sensitive to any of the individual underlying constructs. These results are available on request.

4.4 Sample Difference Tests

We can use a number of contrasts among subsamples of our data to further investigate potential endogeneity or other specification problems. For instance, we construct a measure of adjustment costs by creating a composite scale (comparable to EXT and WO) for our organizational inhibitor variables, which allows us to segment the sample into firms that have high and low organizational adjustment costs. Firms facing higher adjustment costs are likely to have been endowed with their organizational complements so our quasi-fixed assumption is most likely to be valid, while firms with lower adjustment costs are more likely undergoing change to more modern work practices. If unusually high performing firms are also likely to be investing in decentralized work practices, we would expect the endogeneity problem to be concentrated in the low adjustment cost firms. In Columns (1) and (2) of Table 10, we report regression estimates for the subsamples of firms that have lower than average and higher than average adjustment costs, respectively, and find results that suggest our analyses are not biased upwards by endogeneity. The coefficient estimate on the 3-way interaction term for firms with lower organizational adjustment costs is .085 (t=2.30), very similar to our baseline estimate, and we cannot reject the hypothesis that the coefficient on the 3-way interaction term is the same across the two regressions. 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 for other specification problems by varying the length and sample frame of our panel. In particular, our organizational practice measures are likely to accurately reflect actual practices in the interval around 2001, and be less accurate in the early and late years. Moreover, if firms adopt these practices over time as IT prices decline, as our theory would predict, we will likely overstate the use of these practices in early periods, and understate them in later periods. In Column (3), when we restrict the sample to a five-year panel close to 2001, we obtain estimates similar to our full estimates in Table 9, and we cannot reject the hypothesis that the coefficients on the 3-way interaction term are the same across the two regressions. In Columns (4) and (5), we run separate regressions from 1999-2001 and from 2002-2006. The higher coefficient estimates on the organizational measures in the 1999-2001 period is consistent with the interpretation that our survey measures understate organizational differences before 2001 and overstate them after 2001. Overall, our estimates in (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.

In Table 11, we implement a series of tests for complementarities proposed by Brynjolfsson and Milgrom (2009) that contrast the productivity of firms that have adopted different combinations of IT, EXT and WO. We first dichotomize each of the three variables where a 1 represents high levels of the organizational practice, and a 0 represents low levels. The highest productivity group is that in which firms invest in all three factors (1, 1, 1), where the values are average productivity differences relative to the (0, 0, 0) group. F-tests indicate that the productivity differences between the (1, 1, 1) group and groups with any combination of two factors are all significant at the 5% level. Furthermore, the point estimates on the off-diagonal terms are negative, although they are not significant. This pattern of results is precisely what would be predicted by the complementarities story, and provides additional evidence that our results are not being driven by endogenous organizational investment. Although reverse causality between performance and organizational investment might explain the (1,1,1) quadrant, it does not explain why firms that have neither factor in place would be more productive than those with one but not the other in place. Furthermore, Chi-squared tests (shown with Table 11) indicate that the majority of firms appear to cluster into one of the two main diagonal quadrants within this group, as would be expected given the observed productivity differences and the expected clustering of complementary practices. Interestingly, these results also suggest that even for low IT firms combination of decentralization and external focus appears to provide benefits that are independent of IT investment levels, consistent with the positive EXTxWO cross-term in our regression analysis.

Complementarities arguments also predict that the marginal benefit of adopting a practice should be increasing in the presence of complementary practices. As noted by Aral, Brynjolfsson and Wu (2009) and Brynjolfsson and Milgrom (2009) this can be viewed as movements along the edges of a cube where each axis represents one of the (dichotomized) practice measures (see Figure 2). This increasing returns argument implies three specific tests of movement along an edge, plus a fourth test that considers all three movements. For instance, one test is whether the adoption of EXT adds greater benefit in the presence of IT and WO [the movement from (1,1,0) -> (1,1,1)] than adoption EXT alone [the movement from (0,0,0) -> (0,0,1)]. The results of these tests suggest that the benefits of adopting external focus in the presence of IT and decentralization are greater than the benefits of adopting external focus alone ($p<.01$), and the benefits of adopting decentralization are increasing in the presence of IT and external focus ($p<.05$). IT adoption also provides greater productivity benefits in the presence of decentralization and external focus, but this is not significant, perhaps due to the substantial complementarity between external focus and decentralization alone. Finally, we reject the null hypothesis of no increasing returns when we consider all three changes simultaneously ($p<.01$).

The findings from Table 11 and Figure 2 are visually captured in Figure 3, in which we show a plot of fitted values from a regression of organizational and IT inputs on the productivity residuals when other variables have been netted out. Lighter areas in Figure 3 correspond to higher productivity values. The “saddle” shape of the surface is consistent with a complementarities argument between external and internal information processing practices. Firms that invest in both sets of practices appear to do particularly well, but firms that invest in neither set of practices perform better than firms that invest in only one or the other set of practices.

5. Conclusion

Our results suggest that a 3-way system of complements that includes external focus, decentralization, and IT intensity is associated with productivity in modern firms. IT is only positively and significantly associated with productivity for firms that simultaneously have the right organizational structures in place, whether through wise management or luck. While prior work has demonstrated the importance of decentralization in explaining differences in returns to IT investment, the central contribution of this paper is the integration of the external focus variable into the IT productivity framework.

Our hypothesis that decentralized decision-making and external focus are complementary to IT investment is supported by a number of different analyses. First, these three factors are highly correlated, indicating that firms are likely to invest in them together. This pattern of joint investment is predicted if managers are at least somewhat aware of these complementarities or if competition selects for companies with more productive combinations of practices. We also found evidence that one of the principal mechanisms through which external focus affects productivity is via improved product development. Some of the strongest evidence of complementarities comes from our production function estimates — 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 essentially 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 through external linkages with other firms, rather than within insular firms. Information technologies appear to provide greater benefits for firms that must process information effectively to respond to frequent environmental signals. This observation is also consistent with recent research suggesting cross-regional in returns to IT adoption, since these complementarities are likely to be most valuable when firms are located in information-rich environments. Finally, from a research methods standpoint, we have identified an effective set of instruments for work organization and external focus, providing greater confidence that these and prior results on the benefits of IT-related organizational 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 advances in IT and workplace organization. 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 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 through external practices such as competitive benchmarking and inter-organizational product teams. Thus, while the two types of organizational practices are complementary, external focus is distinct from organizational decentralization both theoretically and empirically. However, it is likely that our measures represent a wider set of practices that firms use to bring information into the organization.

Our findings may also have implications for policy makers. There has been recent discussion of why IT appears to have led to greater productivity growth in some regions within the US than in others, and in some parts of the world than others (Dewan and Kraemer, 2000; Bloom, Sadun, and Van Reenen, 2008). Our findings suggest that the degree to which firms are networked with customers, suppliers, and partners 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 share information across regions (Saxenian, 1996).

There are some important 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. We expect that future research using more fine-grained measures of organization will continue to identify other organizational and management practices that interact with technology to affect productivity and innovation.

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Table 1: Organizational Practice and Human Capital Survey Variables

	Range	N	Mean	Std. Dev.
External Focus				
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 in 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: External Focus Measure

	Kohli, Jaworski, & Kumar (1993)	*Mendelson & Pillai (1999)*	*Tambe, Hitt, & Brynjolfsson (2011)*
Measure	Intelligence Generation[a]	External Information[b]	External Focus
Definition	The collection and assessment of both customer needs/ preferences and the forces (i.e., task and macro environments) that influence the development and refinement of those needs.	Whether the organization has receptors to sense changes in the external environment and provide it with quick and accurate feedback.	External information practices used to detect environmental changes
Information Scope	Customer Preferences	Technology, Product Markets, Customers, and Competitors	Technology, Product Markets, Customers, and Competitors
Industry Scope	All sectors	IT Hardware Manufacturing	All Sectors
Scale Items Used	1. In this business unit, we meet with customers at least once a year to find out what products and services they will need in the future. 2. In this business unit, we do a lot of in-house market research. 3. We are slow to detect changes in customer's product preferences. 4. We poll end users at least once a year to assess the quality of our products and services. 5. We are slow to detect fundamental shifts in our industry (e.g., competition, technology, regulation) 6. We periodically review the likely effect of changes in our business environment (e.g., regulation) on customers.	1. How important are direct discussions with customers and input from marketing personnel, as sources of ideas for product development? 2. How important are customer preferences in defining your cost reduction targets? 3. On what basis do you set order throughput time targets?	1. Project teams often include employees from customers, suppliers, or business partners 2. Competitive benchmarks are regularly used in corporate strategic planning. 3. We are usually the leading edge adopter of new technologies in our industry. 4. Executives devote a significant part of their time to recruiting. 5. We are successful in attracting new employees because we pay better than industry average.

[a] Intelligence generation is one element of "Market Orientation" along with intelligence dissemination and responsiveness.
[b]Awareness of external Information is one element of the 'Information Age Organization', along with decentralization, incentives, internal knowledge dissemination, learning by doing, internal focus, and inter-organizational networks.

Table 3: Correlations for Variables Used in External Focus Measure

	BENCHMARK	*PROJTEAM*	*EXECRCRT*	*NEWEMP*	*NEWTECH*
BENCHMARK	1.0				
PROJTEAM	.22	1.0			
EXECRCRT	.13	.13	1.0		
NEWEMP	.17	.23	.25	1.0	
NEWTECH	.27	.07	.10	.28	1.0
N=201					

Table 4: Comparison of Occupational Distribution in Sample of Domestic IT Workers with 2006 Occupational Employment Survey (OES)

Occupation	IT Worker Sample	OES
Computer & IS Managers	.18	.10
Computer Support Specialists	.26	.20
Systems Analysts & Programming	.37	.50
Network and Data Communications	.19	.20

Table 5: 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
†Survey variables.									

Table 6: 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(IT Employment)	*LITEMPLOY*	4.61	1.68
Log(Capital)	*LCAP*	6.01	2.02
N=181			

Table 7: Correlations Between Organizational Practices, IT Measures, and Organizational Inhibitors

	External Focus (EXT)	Decentralization (WO)
Log(% Email)	.24***	.25***
Log(% PC)	.18**	.16**
Log(IT Emp)	.21*	.17**
WO	.45***	
ADJ	-.24***	-.28***
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 8: Regressions of IT and Organizational Practices on Product Development Measures

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	FIRST	*SPEED*	*PLMGMT*	*FIRST*	*SPEED*	*PLMGMT*
	OLS	OLS	OLS	2SLS	2SLS	2SLS
External Focus (*EXT*)	0.310***	-0.076	0.294***	0.437***	-0.045	0.079
	(0.090)	(0.097)	(0.094)	(0.134)	(0.144)	(0.142)
Decentralization (*WO*)	0.040	0.125	0.152*	-0.149	0.007	0.335**
	(0.086)	(0.093)	(0.090)	(0.146)	(0.157)	(0.154)
Log(%Email)	0.051	0.267**	-0.170	0.085	0.281**	-0.154
	(0.117)	(0.127)	(0.123)	(0.119)	(0.128)	(0.126)
Log(R&D Intensity)	0.045	0.200**	0.018	-0.008	0.175**	0.045
	(0.072)	(0.078)	(0.076)	(0.073)	(0.079)	(0.077)
Controls	Industry %College	Industry %College	Industry %College	Industry %College	Industry %College	Industry %College
Hausman Test				p=.143	p=.563	p=.124
Observations	135	135	135	128	128	128
R-squared	0.23	0.17	0.24	.21	.15	.20

Huber-White robust standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%. 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. *PLMGMT* is a measure of internal product line management, and it 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. All first-stage regressions in (4)-(6) have an R^2 of at least .42. The Hausman Test is a test of the null hypothesis that OLS is inconsistent.

Table 9: Regressions of IT and Organizational Practices on Productivity Measures

	1999-2006	1999-2006	1999-2006	1999-2006	1999-2006	1999-2006	1999-2006
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
DV: Log(VA)	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**	**OLS**	**2SLS**
Log(Capital)	0.323***	0.303***	0.319***	0.317***	0.312***	.132***	0.332***
	(0.032)	(0.030)	(0.029)	(0.029)	(0.034)	(.043)	(0.050)
Log(Non-IT Emp)	0.582***	0.595***	0.579***	0.616***	0.643***	.891***	0.642***
	(0.056)	(0.053)	(0.057)	(0.048)	(0.055)	(.054)	(0.066)
Log(IT Emp)	0.076*	0.069*	0.071*	0.022	-0.002	-.050	-0.028
	(0.038)	(0.037)	(0.039)	(0.037)	(0.040)	(.029)	(0.049)
WO		0.184		0.103	0.149	.054	0.118
		(0.166)		(0.153)	(0.141)	(.131)	(0.377)
WO x IT		0.020		0.002	0.016	.004	-0.011
		(0.037)		(0.033)	(0.030)	(.026)	(0.087)
EXT			0.122	0.014	-0.068	.047	-0.027
			(0.189)	(0.168)	(0.157)	(.152)	(0.574)
EXT x IT			0.014	0.006	-0.016	.009	0.018
			(0.044)	(0.038)	(0.036)	(.034)	(0.138)
EXT x *WO*				0.429***	0.387***	.365***	0.847**
				(0.123)	(0.126)	(.116)	(0.338)
WO x *EXT* x IT				0.099***	0.090***	.098***	0.179**
				(0.032)	(0.032)	(.029)	(0.082)
Controls	1 digit Industry, Year	1 digit Industry, Year	1 digit Industry, Year	1 digit Industry, Year	1 digit Industry, Year, %Skilled, %Prof	2 digit Industry, Year, %Skilled, %Prof, %High, % Coll	Industry, Year
Hansen J							0.436
Anderson CC							84.7, p<.000
Hausman Test							0.617
Observations	813	813	813	813	769	769	813
R^2	0.92	0.93	0.93	0.93	0.93	0.95	0.92

Huber-White robust standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%. Errors are clustered on firm. IT Employment, Non-IT Employment and Capital are in logs. Dependent variable in all regressions is Log(Value Added). All first-stage regressions in (6) have an R^2 of at least .22. The Hansen J Statistic tests the null hypothesis that the instrumental variables are uncorrelated with the residual terms (exclusion restriction). Anderson tests the correlations between the endogenous regressors and instrumental variables, and therefore, for instrument weakness. The Hausman Test tests the null hypothesis that OLS is inconsistent.

Table 10: Sensitivity Tests to Quasi-Fixed Organizational Assumptions

DV: Log(Value Added)	**1999-2006**	**1999-2006**	**1999-2003**	**1999-2001**	**2002-2006**
	(1)	(2)	(3)	(4)	(5)
	Low Adj Cost	High Adj Cost	All	All	All
Log(Capital)	0.294***	0.333***	0.300***	0.319***	0.312***
	(0.060)	(0.035)	(0.035)	(0.039)	(0.031)
Log(Non-IT Employment)	0.647***	0.564***	0.614***	0.627***	0.611***
	(0.081)	(0.055)	(0.055)	(0.076)	(0.045)
Log(IT Employment)	0.000	0.067	0.030	-0.007	0.038
	(0.055)	(0.051)	(0.040)	(0.056)	(0.038)
EXT	0.055	-0.034	-0.136	-0.400	0.213
	(0.228)	(0.246)	(0.185)	(0.296)	(0.154)
WO x IT	0.155	-0.259	0.015	0.227	0.024
	(0.249)	(0.264)	(0.039)	(0.244)	(0.144)
EXT x *WO*	0.354**	0.610***	0.370**	0.551**	0.404***
	(0.159)	(0.186)	(0.142)	(0.232)	(0.117)
EXT x IT	0.020	-0.007	-0.033	-0.095	0.055
	(0.050)	(0.058)	(0.043)	(0.068)	(0.035)
WO x IT	0.020	-0.089	0.015	0.032	-0.015
	(0.053)	(0.055)	(0.039)	(0.053)	(0.031)
WO x *EXT* x IT	0.085**	0.140***	0.082**	0.124**	0.097***
	(0.037)	(0.047)	(0.037)	(0.057)	(0.031)
Controls	Industry, Year	Industry, Year	Industry, Year	Industry, Year	Industry Year
Observations	424	389	528	316	497
R-squared	0.93	0.94	0.92	0.91	0.95
Huber-White robust standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%. Errors are clustered on firm.					

Table 11: Productivity with Matches and Mismatches on Complements

	IT=1	
EXT \ *WO*	1	0
1	.406*** (.104) N=74	-.043 (.120) N=32
0	-.267 (.268) N=29	.020 (.160) N=49

Huber-White robust standard errors are shown in parentheses and clustered on firm.
Pearson Chi-Sq(1)=19.4, p<0.01.

	IT=0	
EXT \ *WO*	1	0
1	.199* (.105) N=74	-.021 (.146) N=10
0	-.000 (.105) N=33	0 (N/A) N=61

Huber-White robust standard errors are shown in parentheses and clustered on firm
Pearson Chi-Sq(1)=51.9, p<0.01

Figure 1

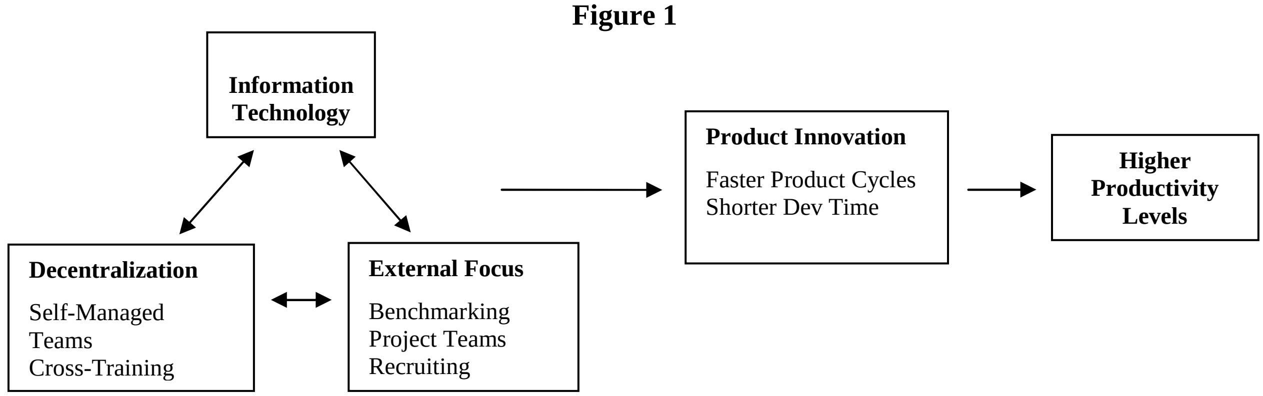
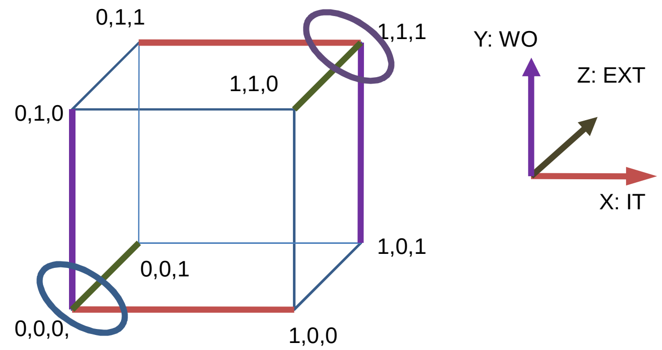


Figure 2: Cube View of Complementarities Between IT, WO, and EXT

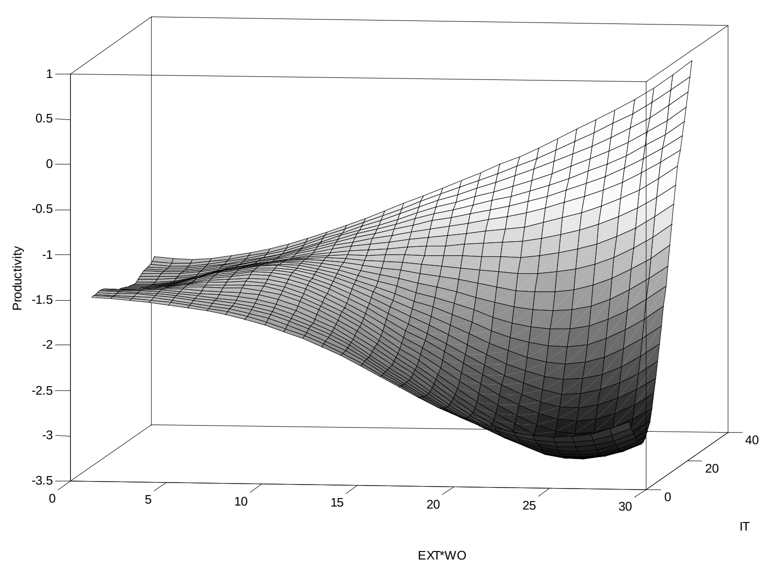


4 tests of complementaries:

1. IT: F(1,1,1) – F(0,1,1) > F(1,0,0) – F(0,0,0) Fail p=.333
2. WO: F(1,1,1) – F(1,0,1) > F(0,1,0) – F(0,0,0) ✓ p=.043
3. EXT: F(1,1,1) – F(1,1,0) > F(0,0,1) – F(0,0,0) ✓ p=.007

4. The system:
[F(1,1,1) – F(0,1,1)] + [F(1,1,1) – F(1,0,1)] + [F(1,1,1) – F(1,1,0)] -
[F(1,0,0) – F(0,0,0)] + [F(0,1,0) – F(0,0,0)] + [F(0,0,1) – F(0,0,0)] > 0
✓ p=.008

Figure 3: Level Plots of Fitted Values from Regression of Productivity on External Focus, Workplace Organization, and Information Technology



Notes: From authors' regressions. z-axis is log(value added).

SUPPLEMENT: TESTS USING INDIVIDUAL EXTERNAL FOCUS MEASURES

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
DV: Log(VA)	***BNCHMRK***	***NEWTECH***	***NEWEMP***	***EXECRCT***	***PROJTEAM***	***BNCHMRK NEWTECH PROJTEAM***	***NEWEMP EXECRCT***
IT	.068*	.057	.045	.041	.009	.025	.042
	(.037)	(.041)	(.036)	(.035)	(.038)	(.037)	(.038)
WO	.093	.159	.142	.284*	-.006	-.023	.290
	(.159)	(.177)	(.155)	(.169)	(.160)	(.149)	(.171)
WO x IT	.005	.015	.015	.039	-.026	-.026	.042
	(.031)	(.038)	(.034)	(.037)	(.036)	(.034)	(.037)
EXT	.093	.068	.042	-.298**	.208	.181	-.236*
	(.159)	(.175)	(.204)	(.113)	(.213)	(.192)	(.142)
EXT x IT	.021	.010	.008	-.061**	.055	.045	-.049
	(.040)	(.040)	(.048)	(.025)	(.051)	(.048)	(.032)
EXT x *WO*	.330**	.126	.290**	.178	.544	.469***	.242**
	(.151)	(.159)	(.128)	(.091)*	(.121)	(.137)	(.106)
WO x *EXT* x IT	.062	.035	.065**	.044*	.135***	.107***	.057**
	(.038)	(.036)	(.032)	(.024)	(.032)	(.034)	(.025)
Observations	813	813	813	813	813	813	813
R^2	.93	.93	.93	.93	.93	.93	.93

In the above table, we report results from our main regressions (the specification shown in Table 9, Column (4)) where we vary the construction of our external focus measure. In Columns (1) through (5), we test each of the external focus constructs individually. In Column (6), we report results when using only the three practices most closely related to those investigated in earlier research (Mendelson, 2000). In Column (6), we report results when only using the labor market variables. This set of regressions indicates that our results are not sensitive to any single underlying construct, and instead represent a broader firm orientation towards external information acquisition.

Huber-White robust standard errors in parentheses, * significant at 10%; ** significant at 5%; *** significant at 1%. Errors are clustered on firm. Dependent variable in all regressions is Log(Value Added). Regressions are from baseline model in Column (4) of Table 7, and also include Capital, Non-IT Employment, and controls for 1-digit industry and year.