Testing Three-Way Complementarities: Performance Pay, Monitoring and Information Technology

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We find three-way complementarities among IT, performance pay, and monitoring practices. We model these practices as a tightly-knit incentive system that produces the largest productivity premium when implemented in concert. We assess our model by combining fine-grained data on Human Capital Management (HCM) software adoption with detailed survey data on performance pay and monitoring practices at 90 firms from 1995-2006. HCM adoption is associated with a disproportionately large productivity premium when it is implemented within a system of organizational incentives that includes both monitoring and performance pay, but has little benefit when adopted alone. We find no evidence of reverse causality: the complementarities appear when the software goes live, not when the purchase decision is made. Furthermore, we can distinguish two components of performance pay: motivation (inducing employees to increase effort), and talent selection (attracting higher quality employees). We find that the complementarities are entirely explained by talent selection.

Keywords: Incentive Systems, Information Technology, Complementarity, Enterprise Systems, ERP, Productivity, Production Function, Principal Agent Model.
Introduction

Substantial variation exists in the returns to information technology (IT) investments across firms (Brynjolfsson & Hitt 1995; Hitt & Brynjolfsson 1995, Aral & Weill 2007). One reason for this variation may be differences in the adoption of complementary organizational practices (Bresnahan, Brynjolfsson and Hitt 2002; Ichniowski & Shaw 2003). As IT investments grew dramatically in the 1980s and 1990s, there was also a parallel uptick in the adoption of one such complementary practice—pay-for-performance incentive compensation policies—by U.S. firms (Ichniowski & Shaw 2003). Economists have recently begun to examine the performance implications of such incentive compensation plans and, as in the case of IT, there is substantial variation in their effectiveness. As a consequence, managers and economists alike continue to debate whether these new human resource practices have value (Ichniowski & Shaw 2003). In this paper we propose that these two phenomena are related and specifically that the returns to IT and incentive schemes depend on one another.

We argue that organizational incentive schemes rely on the ability to observe, measure, document and track performance accurately and transparently in order to appropriately reward those who excel; and that information technologies designed to deliver such capabilities complement these incentive schemes. We develop an analytical model that demonstrates this complementarity and argue that the co-presence of IT and incentive schemes should explain variation in both the returns to IT and the effectiveness of performance pay contracts and performance monitoring. We also examine the underlying economic mechanisms which drive this complementarity. Two theories exist to explain how incentive schemes may improve performance: 1) motivating employees to contribute greater effort and 2) through a selection process whereby incentives help attract and retain high quality labor while eliminating underperformers (Lazear 2000, Paarsch and Shearer 2000). We observe variations in firm policy which allow us to distinguish which of two effects contributes to the complementarities we observe. Further, we argue that effective incentive schemes are made up of a tightly knit incentive ‘system’ that combines performance pay with performance monitoring using information technology. We hypothesize that providing performance pay without technologies that enable effective performance monitoring creates adverse incentives or no incentive at all, and that monitoring technologies implemented without performance pay are also less effective. Our goals are two-fold: to examine the complementarities among IT, monitoring and performance pay in order to determine whether these practices can be effectively implemented piecemeal or rather must be introduced as a ‘system of practices’ (Milgrom & Roberts 1990), and to distinguish the mechanisms through which this system of incentives and technology impact productivity and performance.

To explore such fine-grained propositions, we narrow our investigation to the adoption of a specific technology—Human Capital Management (HCM) solutions found in typical Enterprise Resource Planning (ERP) systems. ERP systems provide an ideal test bed for studying IT business value as these “process-enabling technologies” represent firm-wide suites of business software and hardware designed to generate productivity and business value by supporting specific business processes (McAfee 2003). Aral et. al. (2006) demonstrate the existence of a virtuous cycle of productivity and performance returns to enterprise systems. In this cycle, firms that invest in ERP experience greater productivity on average, motivating additional investments in extended enterprise systems such as Supply Chain Management (SCM) and Customer Relationship Management (CRM), creating a cycle of escalating returns. In this paper, we examine the mechanisms driving this virtuous cycle. We collected detailed data on the purchase and go-live decisions of 189 enterprise systems adopters from the sales database of a large enterprise systems vendor from 1995 to 2006. We were able to separate the purchase of IT from the actual use of IT, which for HCM systems may occur years later. By doing so, we address the potential endogeneity of the relationship between IT and productivity. We then gathered a unique data set surveying the detailed human resource practices of these 189 firms in 2005, of which half adopted the HCM system. By focusing on a narrow set of technologies, we explore precisely how HCM systems complement the specific set of business processes they are designed to support. Combining data on technology adoption, financial performance, and human resource practices, we estimate how monitoring and performance pay complement HCM systems to generate a productivity premium.

Theory and Literature

Information Technology and Organizational Complementarities

Since the early 1990’s, firm-level evidence has documented productivity and performance gains for IT-intensive firms (Brynjolfsson & Hitt 2002 provide a review). However, substantial variation exists in the returns to IT spending across firms (Hitt & Brynjolfsson 1995). A leading explanation for this variation is that firms with higher
returns simultaneously adopt complementary organizational practices that produce productivity and performance premiums (Aral & Weill 2007, Bresnahan et al 2002; Caroli and Van Reenen 2002; Brynjolfsson, Hitt and Yang 1998, Bloom et. al. 2008). The value of IT investment is magnified by co-investment in organizational practices. Using market value regressions, Brynjolfsson, Hitt and Yang (2002) find that one dollar of IT investment is associated with ten dollars of market value, where nine of those dollars can be attributed to complementary organizational investments. They find that markets reward firms that invest in IT only when they have also made appropriate organizational investments (Brynjolfsson, Hitt, and Yang, 2002). As information technology investments lower the cost of information transfer, it is hypothesized that IT adoption is especially beneficial for firms that use teamwork and decentralized decision-making (Bresnahan, Brynjolfsson, and Hitt 2002, Caroli and Van Reenen 2001). With a highly skilled workforce that can efficiently use information technology, firms can achieve higher productivity through increased efficiency and customization as line workers are empowered with more decision rights. Furthermore, IT and organizational investments such as those in innovative people management practices can help explain why the US has experienced sustained increases in productivity growth in the last decade while Europe has not (Bloom et. al. 2008).

Most of the literature on IT and organizational co-investment has focused on general-purpose information technologies and organizational practices (Bresnahan & Trajtenberg, 1995). Given the general-purpose flexibility of IT, the number of IT employees or to estimate the total dollars spent on hardware purchases. However, prior research has shown that investments in different types of IT have orthogonal and at times competing performance predominant approach to measuring IT investment has simply been to count implications (Aral & Weill 2007). While aggregate measures of information processing capabilities inside firms are a good first step for understanding how IT-intensive firms experience greater productivity premiums, a more precise view of IT and organizational complementarity is possible with explorations of complementarities between particular technologies and the specific systems of practices they are intended to support (Aral & Weill 2007, Bartel et al 2007).

**Human Capital Management Software**

Human Capital Management (HCM) Software is a part of the Enterprise Resource Planning (ERP) suite of systems. It is an ideal choice for studying how a specific technology complements a specific set of organizational practices to improve productivity. The main purpose of HCM is to equip executives, HR professionals, and line managers with a broad range of workforce support, including accurate planning on performance pay, and the ability to continuously monitor actual work performance. By tightly linking human resource data with other operational and financial systems, HCM enables managers to understand the demand on human capital, track workforce costs, align the goals of employees with the organization’s overall strategy, and to measure employee, division and firm performance.

For example, HCM allows the firm to monitor employee performance. It keeps detailed records of employees’ attendance, such as time worked, overtime, illnesses and vacation time. HCM can also track detailed records of each task performed. Using the HCM system, the worker can provide a brief description of the task, the beginning and the end time of the task as well as the materials used. Snapshots of the software interface in the Appendix1 show in detail the type of information that the system can potentially capture.

**Estimating returns to enterprise software**

Although enterprise systems, such as HCM, constitute a large share of IT investments, especially for large and medium sized enterprises, empirical evidence examining the productivity and performance implications of these investments is sparse. In particular, we lack large-scale empirical evidence on complementarities between specific organizational practices and HCM or ERP investment in general. Hitt, Wu and Zhou. (2002) provide one of the first large-scale statistical analyses of the productivity and performance impact of ERP adoption. By examining 350 publicly traded firms from 1986 to 1998, they demonstrate that ERP implementation is associated with positive productivity and performance gains. Aral, Brynjolfsson and Wu (2006) provide an updated study using ERP adoption data on 698 firms from 1998-2005. By distinguishing the purchase of enterprise systems from their installation and use, this study offers some of the first evidence documenting a potential causal relationship between ERP adoption and firm productivity. The study illustrates the existence of a ‘virtuous cycle’ whereby successful ERP implementations prompt firms to invest in extended enterprise systems and to realize additional performance benefits. However, neither of these studies explicitly tests the complementarity between enterprise systems and organizational co-investments. In this paper, we test how HCM and a specific set of organizational complements—

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an incentive system comprised of performance monitoring and performance based compensation—combine to drive
the ‘virtuous cycle.’

**Human Capital Management Practices**

Our interviews with HCM practitioners and survey results indicate that HCM solutions are used to provide
performance monitoring capabilities, allowing managers to better understand work performance and value created
by employees. To fully leverage the monitoring capabilities provided by the HCM solution, we hypothesize that
firms should simultaneously adopt an appropriate performance pay scheme. We use a principal-agent model with
adverse selection to determine whether performance monitoring and performance pay form a system of
organizational practices that complements HCM implementations.

Our theory confirms existing frameworks demonstrating the importance of analyzing a firm’s work policies not “in
isolation but as a part of coherent systems” (Holmstrom & Milgrom 1994, Milgrom & Roberts, 1990, 1995; Kandel &
Lazear, 1992, Aral & Weill 2007). Firms realize the largest productivity gains by adopting clusters of
complementary practices, but benefit little from individual practices alone. Our work is related to Ichniowski et al.
(1997) who find that factories with a cluster of complementary human resource practices are significantly more
productive than those that implement the same practices separately. These practices include performance pay,
teamwork, flexible job assignment, employment security and training. Bartel (2004) documents similar findings in
the banking sector. Through a large-scale empirical study, Black and Lynch (2001, 2004) show how new
technologies, human capital investments and changes in work practices combine to drive productivity.

In the set of papers most closely related to our work, Bartel, Ichniowski and Shaw (2007) analyze several plant-level
mechanisms through which IT promotes productivity growth. By studying one narrowly defined industry—valve
manufacturing—and a specific technology that is used to improve valve-making processes, they find plants that
adopt new IT-enhanced equipment improve productivity by lowering set up times for new product runs. They
subsequently document that IT also shifts firms’ business strategies to produce more customized goods.
Furthermore, IT and the demands for customization prompt changes in skill requirements and work practices needed
to implement the new business strategies. Although their work focuses on a specific technology and its associated
impact on work practices, the authors do not directly test the complementarities between the two. Our work not only
focuses on a specific technology and a set of organizational practices that the technology is designed to support, it
also documents how performance monitoring, HCM adoption, and performance pay, together act as a
complementary system of technology and organizational practice.

Although we are aware that department-level analyses may be beneficial to explore fine-grained human resource
practices, we choose to focus our analysis at the firm level. Department or business unit level analysis can eliminate
heterogeneity introduced at the firm level. However, the decision to adopt enterprise systems such as HCM is
generally made at the firm headquarters, and the scope of enterprise system implementation is usually firm-wide.
Furthermore, because intra-firm transfer pricing need not face a market test (if it even exists at all) the key
performance metrics will be more meaningful and credible when assessed at the firm level. Finally, firm-level
analysis has more direct implications for firm strategy and bottom line business performance than analysis
conducted at the department or business unit level.

**A Principal-Agent Model with Moral Hazard and Adverse Selection**

We use a principal-agent model with both moral hazard and adverse selection to analyze the complementarity of
HCM software and compensation systems that include monitoring policies and performance pay. Our model builds
on the work of Baker (1992) and Prendergast (1999), who examine incentive systems in which both the principal
and the agent are risk neutral, and the agent makes a single effort decision. We differ from these models in two
ways. First, we change the model by incorporating the costs of monitoring created by the adoption of HCM
solutions. Second, we distinguish talents of workers by their disutility of work, whereby skilled workers have a
lower cost to exert the same level of effort than unskilled workers. We show that firms profit more through the use
of an appropriate performance pay scheme if they simultaneously improve their ability to monitor work performance
and prevent employees from gaming the compensation system. In addition, we analyze the profitability impact of
the compensation system and information technology when performance monitoring, performance pay and HCM
systems are simultaneously adopted.

Following Baker (1992), we allow for a divergence between the socially optimal and privately optimal level of
effort. For example, if the agent is rewarded on the total number of patents he produces, he may knowingly file
patents that take little effort but have minimal value to the principal. After all, it is in the agent’s interest to do so, given the incentive structure he faces. We model this scenario by assuming that the principal cannot contract with the agent on the actual output $q$. Instead, the principal observes a performance measure $p$, which he uses to reward the agent. We assume output is a function of the agent’s effort, $a$, as follows:

$$q = a + e_q$$  \hspace{1cm} (1)

where $e_q$ is normally distributed with mean 0 and variance $\sigma_q^2$. The performance signal $p$ is also a function of effort except that indicators of performance are noisy, such that the marginal effect of effort on the performance indicator depends on a scaling factor $a$, while the true marginal productivity of effort is independent of $a$. We assume $a$ is normally distributed with mean 1 and variance $\sigma_a^2$, where $\sigma_a^2$ can be viewed as a direct measure of the degree to which the agent can game the compensation system (Baker, 1992). The error term $e_p$ is also normally distributed with mean 0 and variance $\sigma_p^2$.

$$p = aa + e_p$$  \hspace{1cm} (2)

The risk neutral principal maximizes the profit function which is a function of output $q$, the agent’s wage $w$, and the cost of monitoring $\Gamma(s)$.

$$\Pi = E(q - w - \Gamma(s)), \text{where}\ \Gamma(s) = ks, \sigma_s^2 = \frac{1}{sm}$$  \hspace{1cm} (3)

The cost of using the technology to monitor is a linear function of a constant $k$ and the effort of using the technology to monitor, $s$. To discourage the agent to game the compensation system or to reduce $\sigma_a^2$, the principal must have both the policy ($m$) and the ability ($s$) to monitor employees. When the principal adopts a monitoring technology without explicit monitoring policies, information produced by the technologies will be of no use. Similarly, having the policy to monitor but without having the right technology to observe employees’ actions would be equally ineffective. Thus, the principle can only reduce $\sigma_a^2$ when she possess both the technology and the policy to monitor.

The agent is also risk neutral with a linear utility as a function of wage and a quadratic cost of efforts. The reservation utility is $\bar{V}$.

$$w - \frac{1}{2}ca^2 \geq \bar{V}, \text{where}\ w = t + bp = t + baa + be_p$$  \hspace{1cm} (4)

Wage $w$ is a linear function of the performance measure, with a fixed wage $t$ and a pay-for-performance component at rate of $b$. An agent receives higher compensation by signaling higher performance, $p$, to the principal. Given a contract $(t, b)$, the agent chooses an optimal effort level $a$ to maximize its utility. From the first order condition, we can solve for the optimal effort to be:

$$a = \frac{ab}{c}$$  \hspace{1cm} (5)

Solving the principal’s maximization problem subject to the individual rationality (IR) and incentive compatibility (IC) constraints yields the following results:

$$\pi^* = b - \frac{b^2}{2c}(1 + \sigma_a^2) - k \frac{1}{\sigma_a^2}$$  \hspace{1cm} (6)

If adopting the HCM technology allows the principal to better monitor the agent’s work performance, we expect firm to improve its profitability. Our interviews and surveys indicate that HCM can act as an instrument for reducing the magnitude of $\sigma_a^2$, the ability to game the compensation system. We assume the value of $k$ to be small such that the cost of monitoring is minimal once the HCM system is in place. Typically, HCM systems have large fixed costs with relatively low marginal costs as it takes multiple years of planning and implementation before the system “go live.” However, the incremental cost of using the system is small after it is fully implemented. By reducing the ability for employees to game the system (decreasing $\sigma_a^2$) through improved monitoring, firms should experience higher profits. This effect is characterized by

$$\frac{\partial^2 \pi}{\sigma_a m} = \frac{1}{2c}b^2 \sigma_a^4 - k > 0$$  \hspace{1cm} (7)

However, firms can obtain even greater profits if they increase the power of the incentive, $b$, and their monitoring efforts simultaneously, demonstrating the need to implement these organizational practices together as a system of IT complements. As the principal reduces the ability of the agent to game the compensation system through effective use of monitoring technologies and policies, the introduction of performance pay can direct employees to exert more effort to produce. Acting as a complementary system, performance pay, monitoring policy and monitoring technologies work together as a cluster of organizational practices that improve firm performance. Adopting each separately is less beneficial than adopting them all in concert (Milgrom & Roberts, 1992, Aral & Weil 2007, Brynjolfsson & Milgrom, 2008).

$$\frac{\partial^3 \pi}{\sigma_a^2 m} = \frac{1}{c}b \sigma_a^4 > 0$$  \hspace{1cm} (8)

The second outcome of this model is that performance pay contracts can have a selection effect, attracting and retaining more talented workers in the firm (Lazear 1994). To see this, we extend the above model by assuming that workers privately know their disutility of effort, $c$. Under this adverse selection model, for any linear contract $w$,
only those whose disutility of effort is smaller than $c^*$ will choose to work for the firm. To demonstrate this, we assume that there are only two types of workers, high ability (Type 1) and low ability (Type 2), where the high ability type or the talented workers have a lower disutility of exerting effort than less able workers. Specifically, $\theta$ share of workers are talented with a cost of effort $c = c_1$ while $1-\theta$ share of workers have low abilities with cost of effort $c = c_2$, where $c_1 < c_2$. Assuming the Spence-Mirrlees single-crossing condition, talented workers always have a higher reservation utility than less able workers, $V_1 > V_2$, since the outside option for high ability workers is always better. The optimal contract under this model will differ from the original model with no adverse selection. We show that higher performance pay under adverse selection can lead to the participation of only talented workers. Specifically, we show that the performance pay rate when both types participate is less than the performance pay rate when only the high ability workers participate.

Both types participate using the same contract—Pooling equilibrium

$$t^* = \frac{\theta \left( \frac{1}{c_1} - \frac{1}{c_2} \right)}{2c_2} + \frac{1}{2c_2}$$

Only more able workers participate—Exclusive equilibrium

$$b_1^* = \frac{1}{1 + \sigma_2^2} t_1^* = \frac{\theta \left( \frac{1}{c_1} - \frac{1}{c_2} \right)}{2c_2(1 + \sigma_2^2)}$$

We can see the performance pay rate under the exclusive equilibrium, $b(c_1)$ is greater than the performance pay rate when both types participate, $b(c_1, c_2)$. As the firm raises the performance pay rate, $b$, less able workers drop out while talented workers continue to participate.

$$b(c_1) > b(c_1, c_2)$$  \hspace{1cm} (11)

$$t(c_1) < t(c_1, c_2)$$  \hspace{1cm} (12)

As the principal reduces the ability of the agent to game the compensation system, the principal is more likely to accurately observe and reward high ability workers. Thus, implementing an incentive scheme that retains talented workers can improve firm profits, since firms would no longer need to subsidize low ability workers by offering them a higher fixed salary. Acting as a complementary system, performance pay, monitoring policies and monitoring technologies form a coherent system of organizational practices that improve firm performance. Adopting each separately is less beneficial than adopting them in concert.

**Summary of Model Conclusions and Hypotheses**

The results of our analytical model demonstrate that there should be complementarities between monitoring (having both the technology and policies to monitor) and performance pay. As employees are compensated for stronger observed performance, the ability to monitor performance effectively (to reduce the error in the performance indicators signal of actual output) should improve the appropriate assignment of rewards for performance, reduce the ability of employees to game the system, and improve the firm’s ability to distinguish top performers from weak performers. Since the HCM software is designed in part to help firms monitor key performance indicators in managing their workforce and because monitoring practices themselves are important for effective performance measurement, we expect there are positive interaction effects of performance pay, monitoring practices and adoption of the HCM software in concert, and that adoption of any two components of this system without the third forgoes the benefits of this complementarity. Thus, we do not necessarily expect to observe complementarities between any two components of the system, like HCM and performance pay, unless the third component, in this case monitoring policies, is also present.

**Data and Survey Methods**

We collected detailed data on the enterprise system purchase and go-live decisions of 189 firms that adopted HCM systems from 1995 to 2006. The data include the U.S. sales of a major vendor’s HCM software and are collected directly from the vendor’s sales database. Since these data record separate dates for purchase and go-live events, we can measure technology investment and use, as well as their associated impact on firm performance. We matched these firms with data on their financial performance. Of the 189 firms in our survey, 90 firms are publicly traded with performance data in the COMPUSTAT database. In Table 1, we provide descriptive statistics of the financial data from for these 90 firms. Our human resource practice data is collected from a survey administered to the 189 firms between 2005 and 2006. We obtained the survey from an independent, not-for-profit organization whose

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2 We prove for a separating equilibrium in the Appendix at http://mit.edu/linwu/www/3-way/apendix.pdf.
purpose is to share experiences of firms that adopt ERP to educate them about best practices. The organization is composed of 1750 member corporations and 50,000 individual members. The survey was sent to all the customers of this major ERP vendor that provided HCM adoption data. Since the majority of these customers are also members of this independent user organization, the response rate for the survey was high at 80%. The survey has more than 200 detailed questions about firm-level human resources management practices. All surveyed firms have adopted some form of ERP from the same major vendor that provided the adoption data, but only half of these firms have adopted the HCM software. We use survey responses to understand how the HCM software is used to monitor work performance, and how the current compensation system is implemented. Each question asks about the current coverage of a best practice that firms may have implemented. Participants rank the degree to which their firm has adopted a given practice from 1-5 with a value of 1 indicating that there is no coverage and a value of 5 indicating that the practice is fully adopted by the organization. Definitions and descriptive statistics for all the survey questions are listed in Table 2. To test our hypotheses, we use the survey to construct variables on the level of performance monitoring and performance pay currently implemented by the firms in our sample.

### Table 1: Descriptive Statistics on Firm Financials

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales (MM$)</td>
<td>869</td>
<td>6644.68</td>
<td>12083.91</td>
<td>0</td>
<td>110789</td>
</tr>
<tr>
<td>Employees(M)</td>
<td>808</td>
<td>26.88</td>
<td>61.85</td>
<td>0</td>
<td>484</td>
</tr>
<tr>
<td>Capital(PPE Net) (MM$)</td>
<td>850</td>
<td>2454.86</td>
<td>4267.27</td>
<td>.01</td>
<td>29382</td>
</tr>
</tbody>
</table>


#### Performance Monitoring

The performance-monitoring variable is constructed from 9 survey questions that gauge how firms monitor workers to obtain more accurate performance signals. The questions are divided into three categories. The first category measures how firms monitor performance, to what degree the monitoring systems are integrated with other relevant systems such as financial reporting and sales systems, and whether these business processes support overall firm strategy (M1-M5). Adopting these monitoring practices is beneficial as they deter employees from gaming the compensation system (by reducing $\sigma_\alpha^2$). The second category measures the extent to which firms can directly monitor employees’ effort using detailed attendance and overtime records, and the ability of the firm to verify the productivity impact of these signals (M6-M8). The third category measures transparency (M9). When management clearly communicates the evaluation criteria to employees, it leaves no room for employees to misinterpret where they should exert effort. To construct the performance monitoring variable, we combine all these factors into a single measure where each factor is first normalized (Norm) by subtracting the mean of the scales and dividing by the standard deviation, yielding a measure of performance monitoring with mean zero and a standard deviation of 1.

$$
\text{Monitor} = \text{Norm}(\text{Norm}(M_1) + \text{Norm}(M_2) + \ldots + \text{Norm}(M_9))
$$

Correlations among individual constructs are shown in the Appendix. The correlations are positive but the survey questions are not strongly correlated and the Chronbach’s alpha is 0.30. The low value is due to multidimensionality of monitoring practices since there is little reason to believe that firms adopting any one monitoring practice will necessarily adopt all others. Firm and industry characteristics can also lead to divergent monitoring practices. For example, attendance may be more important for a manufacturing firm than a software engineering firm, since the former requires workers to show up on time to operate machineries while the latter can potentially work from anywhere. Therefore, we may expect manufacturing firms to implement monitoring policies that log detailed records of workers’ attendance, such as practices in M6-M8 while software engineering firms are more likely focus on other types of monitoring practices, such as aligning to the overall firm strategy. Our goal is not to identify which practice is more beneficial, but to evaluate the extent to which a firm monitors its workers. As long as firms monitor work performance, they may reap the economic rewards from monitoring regardless of what the specific monitoring practices they choose to use. Furthermore, to test the validity of including all nine measures into a single component, we have separately introduced these measures into our main regression and find that we cannot reject that all nine practices have the same coefficients. Consequently, we combined them into a single measure of monitoring.

#### Performance pay

Our measures of performance pay practices assess the degree to which firms reward employees for their work performance. Five questions pertaining to performance pay are used to construct the variable. These questions are classified into 2 groups, monetary incentives that motivate employees to perform optimally, and self-selection mechanisms designed to attract and retain high quality employees. Incentives using monetary rewards have the
direct benefit of motivating workers to exert more effort and produce optimally. Self-selection, an indirect benefit of performance pay, enables firms to attract and retain productive workers. Performance pay is likely to help firms retain high performers since they derive higher income as a function of their performance. At the same time, incentive compensation systems can induce poor performers to leave as their relative income is reduced. As incentive compensation takes on a greater share of the overall wage, these effects should be magnified. We measure the impact of motivation and self-selection separately. To calculate the extent to which direct monetary rewards are used to motivate employees, we ask firms the importance of performance pay in the current compensation system, and the degree to which incentives are aligned with business goals (I1 I2 I3). The incentive compensation motivation variable is calculated by normalizing and summing the survey responses, yielding a measure with mean zero and a standard deviation of 1. Chronbach’s alpha for the set of motivation measures is 0.64, reaching an acceptable level to combine them into the same grouping.

\[
Motivation = \text{Norm}(\text{Norm}(I_1) + \text{Norm}(I_2))
\]

Finding the right people and putting their talent to good use is one of the most important goals in any human resources department. Through self-selection, the appropriate compensation plan enables firms to hire and retain the talent they need. To assess this capability, we ask respondents to report the degree to which their firms use compensation plans to attract and retain talent (I4, I5). Chronbach’s alpha is 0.59.

\[
Selection = \text{Norm}(\text{Norm}(I_3) + \text{Norm}(I_4))
\]

We then construct the performance pay variable as the sum of motivation and selection as follows, and we show the correlation matrix for performance pay variables in the Appendix. The correlations are positive and strongly correlated.

\[
\text{PerfPay} = \text{Norm}(\text{Motivation} + \text{Selection})
\]

<table>
<thead>
<tr>
<th>Table 2: Human Resource Practices Survey Variables</th>
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<tbody>
<tr>
<td>Survey Question</td>
</tr>
<tr>
<td>M1 Compensation planning system integrates information with other relevant non HR systems, such as financial systems, OSHA, manufacturing, sales</td>
</tr>
<tr>
<td>M2 HR system allows for a Balanced Scorecard framework which is integrated into department and individual performance appraisal documents and supports benchmarking and continuous improvement</td>
</tr>
<tr>
<td>M3 HR System provides data analysis and reporting tools to support HR policy development and decision making</td>
</tr>
<tr>
<td>M4 HR system allows to analyze workforce data; design, implement and monitor corporate strategies to optimize the workforce; and continuously evaluate how various courses of action might affect business outcomes</td>
</tr>
<tr>
<td>M5 HR system enables HR professionals to develop cost effective resource strategies, by supporting accurate the planning process, allowing to monitor actual performance relative to plan and allowing to simulate multiple planning scenarios or analyze the financial impact of head count changes</td>
</tr>
<tr>
<td>M6 Time worked routed automatically to project accounting/ resource planning systems: Coverage</td>
</tr>
<tr>
<td>M7 Time and attendance system has automated analysis and reporting capabilities to analyze KPIs such as lost time, productivity, cost of absence, overtime or illness</td>
</tr>
<tr>
<td>M8 Time and attendance system accounts for corrections, calculates the impact of the adjustment, and brings it forward to the current period</td>
</tr>
<tr>
<td>M9 Standardized job descriptions and evaluations are available online</td>
</tr>
<tr>
<td>Monitor = Norm(Norm(m1)…+ Norm(m9))</td>
</tr>
<tr>
<td>Performance Monitoring</td>
</tr>
<tr>
<td>I1 Compensation plans are designed to support overall corporate business strategy as well as strategies of individual divisions/departments</td>
</tr>
<tr>
<td>I2 Compensation plans are designed to align pay with performance, and are linked to easily understood KPIs (e.g., corporate, divisional, organizational profitability)</td>
</tr>
<tr>
<td>Motivation = Norm(Norm(I1)+Norm(I2))</td>
</tr>
<tr>
<td>I3 Compensation plans are aligned with resource plans to attract and retain the desired skill set</td>
</tr>
<tr>
<td>I4 Employee performance expectations clearly communicated during Recruiting process.</td>
</tr>
<tr>
<td>Selection= Norm(Norm(I3)+Norm(I4))</td>
</tr>
<tr>
<td>Performance Pay= Norm(Motivation) + Norm(Selection)</td>
</tr>
</tbody>
</table>
In Figure 1, we show the distribution of firms who have adopted performance monitoring and performance pay practices. As these variables are normalized, we divide the graph into four quadrants with the X and Y axis valued at zero. Quadrant 1 contains firms that have both high levels of monitoring practices and performance pay practices, while quadrant 3 contains the opposite. Although firms are present in all four quadrants, the distribution is not entirely even. While a majority of firms are located in quadrants 1 or 3, relatively few are located in quadrants 2 or 4 where firms have high levels of performance monitoring but low levels of performance pay practices, or vice-versa.

We also investigate how monitoring and performance pay practices vary across industries (Table 3). Industries, such as construction and general retail, tend to have high levels of performance pay and monitoring practices, perhaps because firms in these traditional industries are able to measure workers’ output more precisely. For example, construction output is easily observed—counting how many bricks were laid per unit time is not hard to do and reflects actual worker productivity well. For the same reason, industries such as professional, scientific and technical services, where it is hard to measure outputs generated by individual workers, tend to have high levels of performance pay but low levels of monitoring practices.

### Table 3: monitoring & performance-pay practices by industry

<table>
<thead>
<tr>
<th>Industry</th>
<th>#Firms</th>
<th>Monitor avg.</th>
<th>Perf Pay avg.</th>
</tr>
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<td>4</td>
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<td>2.83</td>
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<td>1.67</td>
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<td>2.16</td>
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<td>2.28</td>
<td>3.50</td>
</tr>
<tr>
<td>Manufacturing: food &amp; textile</td>
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<td>2.37</td>
<td>3.49</td>
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<td>Manufacturing: material</td>
<td>8</td>
<td>2.61</td>
<td>2.71</td>
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<tr>
<td>Manufacturing: machinery &amp; electronic products</td>
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<td>3.60</td>
</tr>
<tr>
<td>Administrative Support &amp; Waste Management &amp; Remediation Services</td>
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<td>2.78</td>
<td>3.58</td>
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<td>Retail Trade: general retail</td>
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<td>3.25</td>
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<td>Construction</td>
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**Empirical Methods and Simultaneity Bias**

Having a set of longitudinal IT adoption and financial data as well as a cross-sectional survey on organizational practices allows us to test the complementarities between IT adoption and a system of human resource practices. Empirical tests of complementarity involve demonstrations of the clustering of complements across firms and positive effects of the co-presence of complements on performance (Milgrom and Roberts 1990, Bresnahan et al. 2002, Aral & Weill 2007). Brynjolfsson and Milgrom (2008) suggest two types of statistical tests to prove the existence of complementarities: correlations and performance differences. We first show the correlations among performance pay, monitoring practices and HCM adoption. According to the model, we expect these three practices to form a system of complements and we expect the pair-wise correlation between any two components of the system to be positive only when the third component is also present. In assessing these correlations, we control for transitory shocks to performance by including a dummy variable for each year and industry controls for 15 industry groupings at the ½ digit SIC level. Next, we use performance differences to test the complementarities between HCM and an incentive system that includes performance pay and monitoring. If monitoring, performance pay and use of HCM are complements, we would expect firms that use these practices and technologies in concert to be the most productive. We test this hypothesis using a production function framework. Following the literature on IT-productivity (Brynjolfsson and Hitt 1996, 2000; Hitt, Wu and Zhou, 2002; Aral, Brynjolfsson and Wu, 2006), we adopt a Cobb-Douglas specification. In addition to Labor and Capital inputs, we embed HCM adoption and HR practices into the model to show how firms convert these inputs to outputs.

We first test whether performance monitoring, HCM adoption and performance pay separately impact productivity using the specifications below, where K represents capital, L is the number of employees and HCM represents dummy variables which equal 1 after HCM is ‘live’ in the firm. As shown in our theoretical model, we expect better monitoring capabilities to improve firm performance. We then test whether monitoring, performance pay and HCM
adoption form a system of complements that provides additional performance improvements when used together. From our theoretical model and complementarities theories, if these practices form a system of complements, we expect only the three way interaction, HCM*Monitor*PerfPay, to be positive.

\[
\ln(\text{Sales}) = \alpha + \beta_1 \ln(K) + \beta_2 \ln(L) + \beta_3, \text{HCMInvest} + \beta_4, \text{HCMLive} + \beta_5, \text{Monitor} + \beta_6, \text{PerfPay} + \beta_7, (\text{HCMInvest} * \text{Monitor}) + \beta_8, (\text{HCMInvest} * \text{PerfPay}) + \beta_9, (\text{HCMLive} * \text{Monitor}) + \beta_{10}, (\text{HCMLive} * \text{PerfPay}) + \sum_j \beta_j, \text{IndustryControls} + \sum \beta_j, \text{Year}, + \varepsilon
\]

**Addressing Simultaneity Bias**

There are three sources of endogeneity that may hamper the potential causal interpretation in this empirical model. First, HCM adoption may be endogenous. While we hypothesize that HCM adoption drives firm performance, the reverse is also possible – firms may choose to adopt HCM when they perform well or they experience exogenous shocks to productivity that inspires HCM adoption. To address this potential simultaneity bias, we took advantage of a unique feature in enterprise technology adoption. To adopt an enterprise system such as HCM, firms often experience a lag of several years between the time they decide to invest in the system and the time when the system finally goes live. On average, it takes a firm 2.71 years to complete an implementation of an HCM system from the initial investment to use of the system.

Using similar methodologies as in Aral, Brynjolfsson and Wu (2006), we separately estimate the HCM investment and the go-live event to distinguish firms’ decisions to invest in new technology from the impact of actually using the technology. If firm performance is correlated with the actual use of the technology but uncorrelated with the investment decision, we can reasonably assume that technology drives performance instead of performance driving the technology adoption. Adding HCM investment variable in the model leads in the following regression. Similarly, we would assume HCM Live to be the part of the complementary system instead of HCM investment.

\[
\ln(\text{Sales}) = \alpha + \beta_1 \ln(K) + \beta_2 \ln(L) + \beta_3, \text{HCMInvest} + \beta_4, \text{HCMLive} + \beta_5, \text{Monitor} + \beta_6, \text{PerfPay} + \beta_7, (\text{HCMInvest} * \text{Monitor}) + \beta_8, (\text{HCMInvest} * \text{PerfPay}) + \beta_9, (\text{HCMInvest} * \text{Monitor} * \text{PerfPay}) + \beta_{10}, (\text{HCMLive} * \text{Monitor}) + \beta_{11}, (\text{HCMLive} * \text{PerfPay}) + \beta_{12}, (\text{HCMLive} * \text{Monitor} * \text{PerfPay}) + \sum_j \beta_j, \text{IndustryControls} + \sum \beta_j, \text{Year}, + \varepsilon
\]

A second potential source of endogeneity is that human resource practices such as performance pay and monitoring may be endogenous. Because our human resource practice data is cross-sectional, we cannot directly assess the level of HR practices before and after the HCM adoption. However, we take the advantage of the fact that organizational practices are often quasi-fixed (Applegate, Cash and Mills 1988, Brynjolfsson and Hitt 1996, Milgrom and Robert 1990, Murnane, Levy and Autor 1999; Bresnahan, Brynjolfsson and Hitt, 2001). Thus, our regressions test how cross-firm differences in human resource practices influence the productivity return from investing in HCM.

Under the quasi-fixed assumption, firms that have already implemented performance pay and monitoring practices are more likely to invest in HCM which can empower the effectiveness of these practices. Adopting HCM to monitor employees enables these firms to quickly reap the rewards of using the technology, and consequently, early adoption of HCM for these firms is more likely to be beneficial. Consequently, their demand for HCM would be higher. To test this hypothesis, we estimate a logistic regression of adopting HCM as a function of the existing human resource practices and firm performance.

\[
\ln\left(\frac{\text{Probability of HCM Adoption}}{1-\text{Probability of HCM Adoption}}\right) = \alpha + \sum \beta X + \varepsilon
\]

A third source of endogeneity may arise from omitted third variables that drive HCM adoption, human resource practice adoption and performance. In order to mitigate against possible omitted variables we include industry and time dummies to capture any industry or exogenous temporal shocks to performance or organizational change. We also employ fixed effects specifications to control for time invariant characteristics of firms. For example, if good management is an omitted variable that confounds our results, fixed effects specifications are likely to soak up most of the variance from this variable. Although our organizational factors are cross-sectional, the HCM adoption variables are longitudinal, allowing us to use a fixed-effects specification to estimate coefficients on all time varying variables including those that interact with HCM variables. The fixed-effect specifications give more confidence in our results since they eliminate the influence of any unobservable time-invariant characteristics of firms.

**Results**

**Assessing Complementarities**

Both correlations and productivity differences can be used to test for complementarities (Athey and Stern, 1998; Brynjolfsson and Milgrom, 2010).
The Correlation Test

We first examined the evidence for complementarities between HCM and the cluster of human resource practices. Table 4, 5 and 6 show the pair-wise correlations among monitoring policies, performance pay and HCM adoption, controlling for the number of employees, industries and years. The results show broad support for the simultaneous adoption of a system of incentives and Human Capital Management technologies.

Table 4, shows pair-wise correlations between HCM adoption and performance pay practices using logistic regressions, (since HCM adoption is binary). The negative coefficient on the pair-wise correlation between performance pay and HCM adoption using the full sample seems to indicate that performance pay and HCM are not a part of the complementary system (β = -.057, p < .1; Model 1). However, after separately examining the subsample of firms that have adopted monitoring practices, we see that the correlation between HCM Live and performance pay is positive and significant (β = .058, p < .1; Model 2), suggesting that performance pay and HCM are part of complementary system only when firms simultaneously adopt policies to monitor employees. On the other hand, when a firm does not monitor employees, performance pay is negatively correlated with HCM adoption (albeit not significantly). Together, these results suggest the importance of examining the system of complements together, as pair-wise correlations between elements in the system are misleading.

Table 5 shows pair-wise correlations between HCM adoption and monitoring practices using logistic regressions, (since HCM adoption is binary). Again we see a similar pattern where the correlation between HCM adoption and monitoring policies to be more positive and statistical significant when firms also use performance pay policies. When firms utilize performance pay in compensation schemes, the correlation between performance monitoring and HCM adoption is positive and significant (β = .033, p < .1; Model 2), suggesting that HCM and performance monitoring practices are complements in the presence of performance pay. On the other hand, when performance pay is not used, the correlation between monitoring practices and HCM is not different from zero, demonstrating that monitoring policies and HCM are not complement in the absence of performance pay schemes. The logistic regression in Tables 4 and 5 can also be used to estimate the probability of adopting HCM as a function of firm performance and human resource practices. Assuming a firm’s organizational practices are quasi-fixed, these tables support the hypothesis that a firm is more likely to adopt HCM when it already has policies in place to monitor work performance and simultaneously adopt performance pay compensation to reward workers (Model 2, Table 4, Model 2, Table 5).

Table 6 shows the pair-wise correlations between monitoring and performance pay practices. The correlation between the two sets of practices is positive and significant (β =.433, p<.001; Model 1) when the full sample of firms are used. After we separate the sample by firms’ decision to invest in HCM, monitoring and performance pay practices remain positively correlated, suggesting that they may be complements regardless of HCM.

Lastly, Table 6 shows the pair-wise correlations between monitoring and performance pay practices. The correlation between the two sets of practices is positive and significant (β =.433, p<.001; Model 1) when the full sample of firms are used. After we separate the sample by firms’ decision to invest in HCM, monitoring and performance pay practices remain positively correlated, suggesting that they may be complements regardless of HCM.

The Productivity Test

Table 7 shows the productivity regressions examining our main hypothesis that the combination of performance pay, monitoring practices and monitoring technology drives productivity. We also performed several outlier tests and detect a single firm that has an extraordinarily large influence on all the regressions. We show the results in Table 7 after eliminating the outlier, since our results do not change qualitatively due to outliers. Model 1 uses the standard
Cobb-Douglas production function framework, correlating the log of annual sales with the logs of capital and labor inputs. Coefficients for labor and capital are statistically significant and are within the range of theoretical predictions.

Next we estimate the impact of HCM adoption (defined as the “go-live” date) on performance. To precisely estimate the impact of HCM, we use a fixed-effect specification to eliminate influence from all the time-invariant variables and added seasonality controls for time-specific changes. To address the simultaneity bias in estimating the return from HCM adoption, we separately estimate the investment of HCM from the go-live event, as examining both the go-live and the investment variables together provides estimates that address reverse causality. If firm performance is correlated with the actual use of HCM rather than with investment in the technology, we can reasonably assume that the HCM technology drives firm performance instead of performance driving the investment in HCM software.

Our results in Model 2 show that the estimated parameter of the go-live variable is positive and significant while the p variable is not significantly different from zero. This implies that the decision to purchase HCM is uncorrelated with productivity, while the actual use of the system is correlated (β = .069, p < .05; Model 2). The magnitude of the HCM go-live parameter has an intuitive economic interpretation—firms that adopt the HCM software produce approximately 6.9% greater output holding inputs constant. However, it could be that HCM adoption is highly correlated with adoption of the full ERP suite and that we are picking up some of the productivity effects of ERP adoption as a whole in this estimate. In particular, these estimates imply that simultaneity bias is not affecting our results and lend credence to the argument that HCM adoption drives performance, rather than higher performance leading firms to adopt HCM. While this result gives us some confidence that the relationship between HCM adoption and productivity is causal, we are aware there could be alternate explanations for this pattern of results including lagged performance effects of enterprise systems adoption, and a selection effect. When we add lagged HCM adoption into the model the results do not fundamentally change.

Models 5, 6 and 7 assess the pair-wise interactions among HCM, performance monitoring, performance pay. We find some evidence of two-way complementarities among these practices, but the effect disappears after including a three-way interaction as shown in Model 8. However, the three-way interaction of HCM Live and an incentive system that includes performance monitoring and performance practices becomes positive and significant (β=.445, p<.01; Model 8). This result provides strong evidence for complementarities between the complete incentive system and the HCM technology that supports it. The parameter estimate for the three-way interaction indicates that the productivity effects of a one-standard-deviation increase in the degree to which firms have adopted incentive system practices are 44.5% higher in firms that have also adopted HCM compared to firms that have not adopted HCM. These results suggest that firms with HCM have more effective incentive systems practices on average, controlling for a host of other factors. Model 9 applies a fixed-effect specification to the model. After eliminating influence from time invariant characteristics including cross-sectional organizational practices and characteristics, the coefficients in Model 9 are generally smaller than in Model 8. The interaction using performance monitoring, performance pay and HCM Live remains positive and significant (β = .165, p < .01; Model 9), further supporting evidence of a three-way complementary system. Models 10 and 11 incorporated HCM investment variables and their interaction with monitor and performance pay variables. As we expected, only the three-way interaction with the HCM go-live variable has any statistical significance, demonstrating again that the complementary system of performance pay and monitoring exists only in the presence of a functional IT system.

A “cube view” graphical framework is useful for understanding the complementarities among three-way systems of technology and organizational practices – in our case among performance monitoring, HCM, and performance pay practices. In Figure 3, we present a 1x1x1 cube with the X-axis representing HCM, the Y-axis representing use of performance pay, and the Z-axis representing the extent to which a firm monitors employees. The binary version of the variable is used to label the coordinates in the cube, with 0 indicating a low level of implementation and 1 indicating a high level of implementation. For example, the coordinate (1,1,1) indicates that a firm has HCM and
### Table 7. Productivity Effects of HCM, Monitor and Performance Pay

<table>
<thead>
<tr>
<th>DV: output</th>
<th>ln(Y)</th>
<th>ln(Y)</th>
<th>ln(Y)</th>
<th>ln(Y)</th>
<th>ln(Y)</th>
<th>ln(Y)</th>
<th>ln(Y)</th>
<th>ln(Y)</th>
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</tr>
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<tbody>
<tr>
<td>Fixed Effect</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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<td>.265*** (.026)</td>
<td>.248*** (.026)</td>
<td>.277*** (.025)</td>
<td>.247*** (.025)</td>
<td>.280*** (.025)</td>
<td>.254*** (.037)</td>
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<td>.579*** (.034)</td>
<td>.712*** (.030)</td>
<td>.638*** (.028)</td>
<td>.713*** (.031)</td>
<td>.643*** (.030)</td>
<td>.683*** (.030)</td>
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<tr>
<td>HCM Invest</td>
<td>.043 (.041)</td>
<td>.048 (.071)</td>
<td>.136** (.062)</td>
<td>.050 (.072)</td>
<td>.148** (.063)</td>
<td>.017 (.070)</td>
<td>.017 (.070)</td>
<td>-.011 (.046)</td>
<td>.059 (.083)</td>
<td>-.010 (.051)</td>
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<tr>
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<td>.143*** (.067)</td>
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<td>.057* (.039)</td>
<td>.150* (.068)</td>
<td>.130* (.040)</td>
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<td>.114*** (.037)</td>
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<td>.087* (.049)</td>
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### Control Variables

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*p<.1, **p<.05, ***p<.01. Huber-white robust standard errors are shown in parentheses.

### Table 8. Employee Motivation or a Selection Effect?

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<th>DV: output</th>
<th>ln(Y)</th>
<th>ln(Y)</th>
<th>ln(Y)</th>
<th>ln(Y)</th>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>ln(capital)</td>
<td>.257*** (.035)</td>
<td>.305*** (.035)</td>
<td>.292*** (.037)</td>
<td>.399*** (.037)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>ln(labor)</td>
<td>.688*** (.030)</td>
<td>.651*** (.035)</td>
<td>.648*** (.039)</td>
<td>.439*** (.049)</td>
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<tr>
<td>HCM Invest</td>
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<td>-.021 (.073)</td>
<td>.019 (.045)</td>
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</tr>
<tr>
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<td>.107 (.066)</td>
<td>.100* (.059)</td>
<td>.083** (.038)</td>
<td></td>
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<td>.088** (.035)</td>
<td>.074* (.040)</td>
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<td>.048 (.056)</td>
<td>.091*** (.031)</td>
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<td>-- (.044)</td>
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<tr>
<td>Motivation * HCM</td>
<td>.041 (.043)</td>
<td>.026 (.061)</td>
<td>-- (.061)</td>
<td>-- (.061)</td>
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<tr>
<td>Motivation * Monitor</td>
<td>-.220 (.134)</td>
<td>-.229 (.167)</td>
<td>-- (.167)</td>
<td>-- (.167)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selection</td>
<td>.145*** (.035)</td>
<td>.079*** (.045)</td>
<td>-- (.045)</td>
<td>-- (.045)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selection * HCM</td>
<td>.034 (.093)</td>
<td>.056 (.102)</td>
<td>-- (.102)</td>
<td>-- (.102)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selection * Monitor</td>
<td>.001 (.046)</td>
<td>.003 (.072)</td>
<td>-- (.072)</td>
<td>-- (.072)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sel<em>Mon</em>HCM</td>
<td>.185* (.102)</td>
<td>.373** (.155)</td>
<td>.115 (.155)</td>
<td>-- (.155)</td>
<td></td>
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### Control Variables

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<th>year</th>
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<td>R²</td>
<td>.94</td>
<td>.93</td>
<td>.94</td>
<td>.93</td>
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<td>Obs.</td>
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</tbody>
</table>

*p<.1, **p<.05, ***p<.01. Huber-white standard errors

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performance pay schemes to be disproportionately more productive than firms that have implemented partial systems like coordinate (1,0,0) where firms have implemented HCM but adopt neither performance pay nor monitoring policies. Using the production function framework, we perform the full test of three-way complementarities by comparing if firms that can complete the system of complements (1,1,1), by adopting just one of the three practices—HCM, monitoring and performance pay—experience a greater productivity gain than firms that choose to adopt the same practice but in isolation. We find evidence supporting this claim through a t-test that demonstrates the difference to be highly significant at p=0.0038 (System test). This finding is difficult to explain without a reliance on the three-way complementarities between incentives, monitoring and information technology. These results together provide evidence that technology adoption is complementary to a system of organizational practices that includes monitoring and performance pay. We find that firms experience greater productivity gains from HCM when they practice performance monitoring and adopt performance pay schemes, demonstrating that these organizational practices act as “a system of complements” to HCM adoption. These results highlight the essential nature of systems of complements. Milgrom and Roberts (1990) formally analyze how non-convexities can exist in a firm’s decision to adopt any or all of a set of organizational characteristics that together complement new technology. As the marginal benefit of adopting any one of a complementary set of activities increases with the adoption of the others, adoption of systems of practices (what Milgrom and Roberts 1990 call “groups of activities”) “may not be marginal decision[s].” They argue, “Exploiting such an extensive system of complementarities requires coordinated action between traditionally separate functions” (Milgrom and Roberts 1990, p. 515).

Although we have shown strong evidence of complementarities among information technology, monitoring practices and performance pay practices, we take caution in interpreting the coefficient estimates of the three-way interaction terms. Depending on the empirical method used and whether we exclude outliers, the coefficient estimates varies from 14.3% to 44.5% increase in productivity when a firm uses the HCM technology and simultaneous adopts monitoring and performance pay practices. These coefficients are larger than expected, leading us to believe there are other unobserved organizational practices that are correlated with monitoring and performance pay but missing in the model. This is likely since true organizational complementarities may be far more than a 2-way or 3-way complementarities, but a composition of a large set of interlocking firm practices that complement each other. Most people, even the managers themselves may not even understand the true nature of the complementarities. That is why when Intel builds a new manufacturing plant, it simply created an exact copy of an existing high performing plant, including many seemingly irrelevant details such as the paint of the wall. However, it is important to unlock the mystery of these organizational complements to understand exactly how they enable firms to experience higher productivity. In this paper, we advance our understanding of organizational complements by examining the three-way complementarities among performance pay, monitoring practices and HCM software. In the future, we hope to unravel more components of complementary organizational practices.

**Which Incentive Mechanisms Affect Performance: Motivation or Talent Selection?**

Having found that performance monitoring and performance pay work as a cluster of organizational practices that complement the adoption of HCM solutions, we end by examining two theoretical mechanisms which may enable these complementarities and through which incentive pay may drive productivity gains—employee motivation and self-selection. The first effect, employee motivation, is the direct effect of monetary rewards that motivate workers to exert more effort and produce more output. The second effect, self-selection, is the effect of performance pay on the likelihood that more talented and productive workers are likely to take and keep jobs in which they are disproportionately rewarded, while less productive workers are likely to turn over. When compensation is tied to performance, poor performers whose cost of effort is relatively high are likely leave as performance pay decreases their total compensation and makes the job difficult to justify from the perspective of their individual rationality (IR) constraint. On the other hand, high performers are more likely to stay as they can earn more under performance pay compensation systems. Self-selection allows firms to sort workers by ability even if they cannot observe that ability a priori. True abilities are a part of workers’ private information and are generally unobservable to the employer especially at the beginning of the employment period. Although firms can update their beliefs about a worker’s ability over time, the process is costly and the information obtained may still be inaccurate and incomplete. Acting as a selection device, incentive pay helps firms cheaply identify talent and replace unproductive workers with more productive ones as less talented employees leave voluntarily.

Past empirical work has documented evidence of the dual effects of performance pay. For example, Lazear (1996) shows the impact of changing compensation from a fixed rate to piece-rate plan in a windshield installation factory.
He finds that productivity rose 35% due to this change, and uses the factory’s turnover rate to attribute a third of the productivity benefits to self-selection. Our theoretical model shows that performance pay can directly motivate employees as well as helping firms sort workers by talent. Under our moral hazard model with adverse selection, we expect performance pay to complement monitoring policies and monitoring technology primarily through talent selection. In our empirical analysis, we also quantify the differential effects of motivation and self-selection by separately measuring the effects of organizational practices designed to a) align pay with performance (motivation), and b) use compensation plans to attract and retain talent (self-selection). These proxies for distinguishing the two theoretical mechanisms behind the performance effects of performance pay may be measured with some error. The act of aligning pay with performance will support self-selection, and the articulation of incentive policies will motivate employees, contaminating our results and biasing the differences in performance effects between the two to zero. If we do find differences across these distinct aspects in our proxy measures, it will be in spite of this measurement error.

Table 8 shows the empirical results estimating proxies for motivation and self-selection. Model 1 and Model 2 separately test the effect of motivation and self-selection respectively. The results demonstrate that selection has a stronger individual effect on productivity. While a one standard deviation increase in motivation related performance pay policies is associated with an 8.7% increase in productivity, the interaction effect of motivation, performance monitoring and HCM adoption, $HCMLive*Motivation*Monitor$ is not significantly different from zero (Model 1). However, both self-selection and its interaction effect with performance monitoring and HCM adoption are positive and statistically significant ($\beta_{Selection} = .145, p < .001$; Model 2; $\beta_{Selection*Monitor*HCM} = .185, p<0.1$; Model 2), lending support to the argument that self-selection is the primary driver for improved productivity. In Model 3, we include motivation and self-selection variables in a single regression. The effect from self-selection and its three way interaction with performance monitoring and HCM is even stronger ($\beta_{Selection} = 0.079, p<0.1$, $\beta_{Selection*Monitor*HCM} = .373, p < .05$; Model 3), while none of the parameter estimates relating to motivation are significantly different from zero, demonstrating that HCM and performance monitoring are complements primarily due to the selection mechanism. The t-tests for ($\beta_{Selection} < \beta_{Motivation}$) and ($\beta_{Motivation*Monitor*HCM} < \beta_{Selection*Monitor*HCM}$) are both rejected at the $p<0.001$ level. Firms that adopt HCM see greater returns from the system of incentives primarily through talent selection and retention effects. We suspect that HCM enhances firm’s monitoring abilities such that motivation based incentives are heightened, and that as HCM improves monitoring, poor performers are more motivated to leave firms when they are identified accurately as poor performers and therefore paid less.

**Discussion and Conclusion**

Previous research has found complementarities between information technology and organizational capital. We move this stream of inquiry from a broad perspective of IT as a general-purpose technology, toward examination of a specific “process enabling” technologies designed to support human resource management and specifically incentive management. By studying a specific type of enterprise system, the Human Capital Management solution within the ERP suite, we are able to examine very specific predictions about how information technology complements a narrow set of business practices focused on designing and implementing effective incentive contracts.

We use a principal-agent model with adverse selection to show how incentives affect observable performance. In particular we examine performance monitoring and performance pay as a set of organizational practices that complements HCM. Using a detailed survey of human resource practices and comprehensive objective enterprise IT adoption data, we provide some of the first firm-level evidence on how clusters of human resource practices complement a specific type of information technology. Our analysis uncovers three key results. First, we find that HCM, performance pay, and monitoring practices are mutually correlated. In particular, the demand for HCM is greatest in firms that have adopted the other two practices. Second, these practices generate a disproportionate productivity premium when they are implemented simultaneously as a tightly knit system of organizational incentives. Lastly, we find that the complementarities in our sample are entirely explained by talent selection, and not by changes in employee motivation. Because we have separate data for purchase vs. go live, we can rule out reverse causality as an explanation for the complementarities we find.

These results provide evidence of a three-way complementary system of organizational practices and suggest a path to greater productivity from enterprise IT. Yet, these three-way complementarities may be only part of an even larger complementary system, highlighting the complexity of successful IT implementation strategies.
References


