CEO PAY AND INFORMATION TECHNOLOGY

PRELIMINARY AND INCOMPLETE

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Abstract

Compensation for CEO's and other top executives has increased dramatically in recent decades, drawing increasing scrutiny from policy-makers, researchers, and the broader public. We find that information technology (IT) intensity strongly predicts compensation of top executives. Our examination of panel data from 2507 publicly traded firms over 15 years controls for other types of capital, number of employees, market capitalization, median worker wages, industry turbulence, firm or industry fixed effects, and other factors. Our interpretation of this finding builds on earlier work that found a correlation between CEO pay and firm size. We hypothesize that IT increases the information available to the top executives for decision-making, magnifies their ability to propagate instructions throughout the firm, and improves the monitoring and enforcement of those instructions. When a top executive's instructions are implemented with higher fidelity, the fortunes of the firm will more closely mirror her performance. From the perspective of the top executive, this increases "effective size" of the firm that she controls and thus her marginal productivity. In turn, in an efficient market, this will increase overall executive compensation.

Keywords: executive pay, IT impacts, decision-making, centralization, income inequality, executive compensation

"The mountains are high and the Emperor is far away."
– Chinese Proverb

"The [IT] dashboard is the CEO's killer app, making the gritty details of a business that are often buried deep within a large organization accessible at a glance to senior executives. … Managers can see key changes in their businesses almost instantaneously -- when salespeople falter or quality slides -- and take quick, corrective action."
– Ante (2006)

Introduction

This paper examines the relationship between information technology (IT) and top executives' pay. A substantial rise in top executives' pay for the last three decades has been well-documented (i.e., Hall and Liebman 1998; Hall and Murphy 2003; Bebchuk and Fried 2005; Bebchuk and Grinstein 2005). For instance, the ratio of CEO pay to average worker pay increased from 70 in 1990 to 300 in 2005, widening the income gap between the top earners and median workers.

We examine panel data from 2507 publicly traded firms over 15 years and find that IT intensity is significantly correlated with CEO pay, playing a key role in the recent rise in CEO compensation. The relationship is robust to the inclusion of controls for other types of capital, number of employees, market capitalization, median worker wages, industry turbulence, firm or industry fixed effects, and other factors. Our interpretation of this finding builds on earlier work that ties the increase in CEO pay to the increase in the average size of firms. Specifically, we hypothesize that information technology (IT) has amplified the ability of CEO's decisions to affect the fortunes of whole firm. This increases the *effective size* of the firms that CEOs can influence, resulting in an increase in the marginal productivity of CEOs and thus their pay.

Many researchers have reported that CEO pay is highly correlated with firm size (e.g. Roberts 1956; Barro and Barro 1990; Kostiuk 1990; Rosen 1992). Gabaix and Landier (2008) proposed a model in which the best CEO manages the largest firm at competitive equilibrium as this maximizes the CEO impact. In other words, the CEO of the largest firm has the highest marginal productivity and thus receives the highest pay. Our model extends their work by considering how the *effective size* of the firm varies with both the nominal size and IT intensity. We define the concept of effective firm size as the size of firm that CEO can effectively influence and control. The ability of CEO to manage large firms depends on technology for communicating instructions, replicating processes and monitoring employees. The less perfect the communication between top managers and employees, the less effective the CEO's monitoring and influence becomes. For instance, if a CEO's instructions are accurately propagated throughout only a part of the firm, then the effective size is not as great as it would be if the instructions were accurately and precisely propagated to every part of the firm. Similarly, the ability of the CEO to use IT to better monitor compliance with instructions will also increase the effective size of the firm. The measure of firm size relevant to the marginal productivity of CEO is not the nominal firm size, measured by the number of employees or assets or market capitalization as used in previous literature, but the <u>effective</u> size of firm, measured by the resources that the CEO can actually influence and control. The benefits of having a "superstar" CEO will be greater the larger the effective size of the firm.

We argue that IT can increase the effective size of firm through a variety of mechanisms, and thus we hypothesize that IT-intensive firms pay their CEOs more than those of the same nominal size but with less IT. Examining over 2500 firms in 53 industries from 1992 to 2006, we find that the increase in IT intensity, as defined as the ratio of the IT capital stock to total capital stock, not only explains the difference in CEO pay across industries but is also strongly correlated with the increase in CEO pay over time.

The Role of IT

There has been a radical increase in the use of IT in the US economy in the last few decades. The improvements in the power of IT and the sharp decrease in the price of computers and digital communications have increased the information processing power of American companies by over 33 times during the last two decades. Even in nominal terms, IT stock has grown. Between 1987 and 2004, IT stock per full-time employee (FTE) increased from \$1600 to over \$5100 while the percentage of IT of investment in total tangible wealth from nearly doubled from 12% to over 23% during this period.

Corporations can be thought of as information processors. Hence, these large changes in the costs of digital information processing are likely to affect monitoring and control within firms. In particular, the increases in the quality and quantity of IT have radically affected the ability of top executives to keep informed about activities throughout the organization, and to respond quickly and precisely with instructions. The increase in IT capital and investment in the last two decades has changed and penetrated every step of businesses. Enterprise Resource Planning (ERP) is one example; by now, companies in virtually every industry have adopted ERP despite that it is relatively recent. According to one estimate, spending on these enterprise IT platforms already accounted for over 50% of all U.S. corporate IT investment in 2001 (McAfee 2002). The enterprise IT platforms have enabled a rapid and reliable implementation of a new business practice throughout firms. The retail pharmacy firm CVS provides an illustrative example (McAfee 2005; Brynjolfsson et al. 2007). CVS had a problem of declining customer satisfaction, especially in their core prescription drug fulfillment business. The key problem was identified: there was often a delay in the insurance verification because of incomplete or inaccurate information about customers. Therefore, the management team changed the process. Overall customer satisfaction increased from 86% to 91% using the new system, which represented an enormous improvement.

Most importantly, once CVS had developed an improved prescription drug ordering process, they embedded it in their enterprise IT, which made it possible to rapidly replicate the process to over 4,000 retail stores throughout their entire firm within one year. The IT system assured that each pharmacist would implement the new process exactly as it was designed by management. This rapid and high fidelity firm-wide business process change across thousands of retail stores, enabled by their enterprise IT, led to significant increases in customer retention, increasing the firm value. Contrast this with a pre-IT approach which might have involved sending memos to store managers urging them to adopt each of the steps of the new process and perhaps training sessions exhorting the benefits of changing the procedure and explaining how to do it. In the old system, less than 100% of the store managers would be likely to comply with such a process change even after several years. Thus, the IT-enabled approach to business process replication amplified the impact of management's decision to change a business process. As a result, the firm's market value increased significantly reflecting the rapid and consistent firm-wide implementation of management's decision.

This example illustrates how the effective size of the firm affected by management decisions can be increased as IT facilitates the rapid and reliable implementation of new processes. In particular, the impact of CEO decisions can be magnified by IT as instructions and innovations are propagated, implemented and monitored. In turn, *ceteris paribus*, equilibrium CEO compensation can be expected to increase when the CEO's marginal revenue product is greater.

A related factor which can magnify the impact of CEO decision-making is the complexity and interdependence of business processes. As noted by Milgrom and Roberts (1990) and Brynjolfsson and Milgrom (2010), complementarities can make decentralized decision-making inefficient, highlighting the value of coordination and central leadership by the CEO. Recent research has found that organizational complementarities may be especially important to the effective use of IT (Brynjolfsson and Hitt, 2000; Aral, Brynjolfsson and Wu, 2009) and firm hierarchies tend to be flattened and the number of positions reporting directly to CEO has gone up (Rajan and Wulf, 2006). This trend would also tend to strengthen the relationship between IT and CEO pay.

Related Research

Our study is related to three streams of literature; one is the effect of IT on centralization and decentralization of decision-making, the second is the effect of IT on income inequality, and the third is the rise of CEO compensation.

A large stream of literature studies effects of IT on command, control, coordination, and organization of firms. Rather than reviewing the voluminous literature here, we refer the reader to previous studies (i.e., Leavitt and Whisler 1958; Rule and Attewell 1989; Gurbaxani and Whang 1991; Malone et al. 1987; Brynjolfsson and Mendelson 1993; Brynjolfsson et al. 1994; Brynjolfsson and Hitt 2000) and the literature reviews cited therein. In theory, IT could shift power either toward the center or away from it, leading to centralization or decentralization of a firm. In the former case, IT makes local knowledge available to top managers and management can be more centralized. In this case, one might expect higher CEO relative pay. On the other hand, in the latter case, IT makes local knowledge of one department available to employees (as well as to top managers) in other departments and employees can coordinate tasks among themselves more easily with the need for CEO involvement. In this case, one might expect less CEO relative pay. Ultimately, the net effect is an empirical question. Our study addresses this question by combining data from CPS, Compustat, and BEA and examining the correlation of IT with CEO pay.

Although not directly related to the scope of this study, changes in firm size induced by IT have been also studied based on the economic theories of Coase (1937) and Williamson (1973; 1981). While the effect of IT on firm size is a highly valuable research question, our study does not attempt to answer the question. We take firm size exogenous as numerous studies to research CEO compensations including Gabaix and Landier's paper (2008) have treated. However, it is conceivable that IT changes firm size and the correlation of CEO compensation and IT is mediated by the change of the nominal firm size itself. In our study we concentrate on the change of the effective firm size by IT while the nominal firm size is assumed exogenous. The interpretation of our results with and without this assumption is discussed in the result section.

The second stream of literature to which our study is related is the role of IT in leading to the wage inequality in the whole economy (i.e., Autor et al. 1998). Our view on the role of IT in increasing CEO pay is close to those of Garicano and Ross-Hansberg (Garicano and Rossi-Hansberg 2006; Garicano 2000). They explain that knowledge has hierarchy; some knowledge attached to lower-ranked employee is used to solve a routine problem while other knowledge attached to top managers to process a convoluted non-routine problem. As the cost of communication among agents decreases, the complicated problems that lower-ranked employees cannot solve can be easily passed to their superiors. Once solved, the solution can be disseminated easily with the lowered cost of communication. This can lead to the dependency of the problem-solving on a few "superstars" (Rosen 1981) and thus a higher wage for the superstars. Their explanation is consistent with our view that IT increases the effective size of a firm by easily passing non-routine problems to a few problem solvers and then disseminating the solution to the entire firm. Therefore, the dependency of the IT-intense firm on the few problem solvers and thus the sensitivity of the IT-intense firm to those few superstars become greater, leading to a higher compensation for those superstars in IT-intense firms. The CEOs may or may not be the problem solvers but they are a key to recognize, place, and reward the superstars in their firm. Our model does not, however, imply that a greater wage inequality within the same firm, when the firm is IT-intense, would be observed. Some firms or industries can concentrate many problem-solvers or superstars for the whole economy. The wage inequality within such firms may not be as great as in the whole economy. Our study focus is the differences of CEO pay across time and industry, not the wage inequality within the same firm, as a result of the increased effective size of the firm due to the increased IT intensity. To the best of our knowledge, no previous study has reported the determining power of IT in CEO compensation.

The third stream of literature relevant to our study is studies on CEO compensation. There have been many discussions, theories and explanations for the rise of CEO pay in academia as well as mass media. Following Gabaix and Landier's (2008) summary of the literature on the topic, we recapitulate the literature in four views.

The first is an agency view (Jensen and Murphy 1990; Dow and Raposo 2005; Holmstrom and Kaplan 2001). In order to give incentives or reward to CEOs to cope with more volatile and uncertain business environments and bring more innovative idea in the business strategy, firms have to pay their CEOs more.

The second is a malfunctioning market view (Yermack 1997; Bertrand and Mullainathan 2001; Bebchuk and Fried 2005; Bebchuk et al. 2002; Hall and Murphy 2003). This view is that an efficient market mechanism doesn't work in CEO pay, explaining the rise of CEO pay by an increase in management entrenchment, a loosening of social norms against excessive pay, or simply inability to estimate the true cost of a common type of compensation such as stock-option compensation.

The third is a view on the change of CEO job itself (Frydman 2005). CEO's skills have become more general and they can have more outside options, putting upward pressure on pay.

The fourth view is a market equilibrium view (Gabaix and Landier 2008; Tervio 2008). This view is to explain the rise of CEO pay as the result of the rise in firm size. At market equilibrium, the most talented CEO is matched to the largest firm and paid the highest as the marginal productivity of the most talented CEO is the largest when she is matched to the largest firm and thus the efficiency increases.

Our paper is most closely linked to the market equilibrium view; the increased marginal productivity of CEOs resulted from the increase of firm size is a major determinant of the recent rise of CEO pay. We articulate that what is relevant to the marginal productivity of CEO is an <u>effective</u> size of firm, an increasing function of IT intensity of the firm as well as the nominal firm size. The more IT-intense environment a firm has, the lower the cost of communication and access of knowledge as articulated by Garicano and Rossi-Hansberg (2006) and thus the larger the effective size of the firm becomes. As a result, the impact of CEOs becomes more significant, that is, the marginal productivity of CEO increases. The rise of CEO pay is, therefore, a manifestation of the increased marginal productivity of CEO.

Our argument is also related to the study by Baker and Hall (2004), who explained the CEO pay based on the increased marginal productivity. CEOs perform two kinds of tasks; one is a task to vary with firm size and the other invariant to firm size. For example, a managerial action to buy a corporate jet may affect value of a firm to the same degree regardless of the firm size. A managerial decision to implement new processes or systems throughout a firm, however, will affect the value of a large firm more than that of a small firm. Some managerial decisions affect the value in an absolute amount and others in a percentage. CEOs need to be given an appropriate incentive to take her best efforts to both tasks. Especially when a firm is large the task to affect the firm value in percentage becomes more important and an appropriate incentive to elicit her best effort on the task should be given to the manager. We argue that when a firm is IT-intense as well as large, the impact of CEO decision to affect the firm value in percentage becomes even more important. When a firm is large, implementing a new business process or strategy across multiple departments and branch offices, even if underscored by the top managers, can be slow and prone to uneven and unreliable application of the new process. IT, however, can help a reliable and speedy implementation of the new process in the way anticipated by the top manager upon deciding on the adoption. In other words, the effective size of firm that its CEO can control becomes larger when IT helps her top managerial decision reach the entire firm faster and more reliably.

To examine the robustness of our model, we included other control variables in the analysis. The first was the median worker wage of the industry. Workers' wage difference caused by industry difference has long been recognized (i.e, Katz and Summers 1989; Krueger and Summers 1987; Krueger and Summers 1988; Gibbons and Katz 1992). For example, the median workers' wage in the industry of computer systems and related services, \$65,000, was over 3-times higher than that in the industry of food services, \$18,000, in 2005. The presence of the industry difference in wages has been often explained by factors such as differences in unmeasured abilities of workers across industry, compensating differences, rent sharing, and efficiency wages. Therefore, CEO pay in an industry where median worker wage is high may be high for those reasons. Since we are capturing the industry difference only by IT intensity, there may be an upward omitted variable bias for IT intensity. Our paper does not attempt to identify the cause for the median worker wage difference across industry but takes the cause as a given unknown factor. Therefore, we examined the impact of IT intensity on CEO pay by including the median worker wage as a control variable. Our hypothesis is that IT investment will affect the marginal productivity of top managers more than median workers, resulting in that other industry differences causing median workers' salary will affect CEO pay less once IT investment variable is separated.

The second control variable we included was the industry turbulence. Some researchers have reported that IT-intensive industries tend to be more turbulent than others (Brynjolfsson et al. 2007). It may be that firms in turbulent industries face more competitive business environments and benefit disproportionately from hiring more talented and thus more expensive CEOs. The increased CEO pay due to IT intensity may be a result of the more competitive business environment that the firm faces in her industry not the increased effective size of her firm. The industry turbulence, as defined as the average of rank changes of firms from year to year over industry, was included as a control variable to explore this possibility.

Model

Our model extends the model of Gabaix and Landier (2008), that can be summarized as the following:

1) CEOs have different levels and managerial talent and are matched to firms competitively;

2) in equilibrium, the best and thus the highest paid CEO manages the largest firms, as this maximizes their impact and economic efficiency; and

3) the CEO pay also increases with the average size of firm in the economy.

In other words, this theory states that, if there are two firms of different sizes and two managers of different talent, a competitive equilibrium exists in the way that the larger firm hires the more talented manager at a higher pay than the smaller firm does. Our contribution is to extend the concept of firm size in their theory to an "effective" size of firm, defined as the firm size that top managers can control and reach as information technology has integrated firm data and enabled a replicable, speedy, and firm-wide business process aided by an enterprise IT system, and test the theory with empirical analysis.

We briefly walk through Gabaix and Landier's model here. Consider the problem of hiring a CEO with talent, T, faced by a particular firm. The firm has "baseline" earnings of a_0. At t=0, it hires a manager of talent T for one period. The manager's talent T increases the firm's earnings according to

$$a_1 = a_0(1 + C \times T) = a_0 + a_0 \times C \times T \qquad (1)$$

for some $C > 0$, which quantifies the effect of talent on earnings. Consider one extreme case that the CEO's actions at date 0 impact earnings only in period 1. The firm's earnings are $(a_1, a_0, a_0, \ldots.)$. The other extreme case is that the CEO's actions at date 0 impact earnings permanently. Then the earnings become $(a_1, a_1, a_1, \ldots)$. In both cases, the firm's problem can be written as the following:

$$\max_T S \times (1 + C \times T) - W(T) = \max_T S + S \times C \times T - W(T) \qquad (2)$$

where $S = \frac{a_0}{1+r}$ for the former (where CEO's talent impacts the firm's earnings only the first period) or $\frac{a_0}{r}$ for the latter (where CEO's talent impacts the firm's earnings permanently), r is the discount rate, and $W(T)$ is the wage of CEO with talent, T. Eqn (1) can be generalized as $a_1 = a_0 + C{a_0}^{\gamma} + independent\ factors$, for a non-negative γ. The maximization problem of (2) becomes that:

$$\max_T (S + S^{\gamma} \times C \times T - W(T)) \qquad (3)$$

Let's call $w(m)$ the equilibrium compensation of each CEO with index m which can be thought of the CEO's ranking or quantile in talent. The problem of (3) can be rewritten as that:

$$\max_m (CS(n)^{\gamma} T(m) - w(m)) \qquad (4)$$

A competitive equilibrium consists of:

i. a compensation function $W(T)$, which specifies the market pay of a CEO of talent T, and

ii. an assignment function $M(n)$, which specifies the index $m = M(n)$ of the CEO heading firm n in equilibrium,

such that

iii. each firm chooses its CEO optimally: $M(n) \in arg \max_m (CS(n)^{\gamma} T(m) - W(T(m)))$, and

iv. the CEO market clears, that is each firm gets a CEO.

As in equilibrium there is associative matching: $m = n$,

$$w(n) = \int_N^n CS(u)^{\gamma} T'(u) du + w(N) \qquad (5)$$

Assuming a specific functional form for $T'(u)$ with the use of the extreme value theory, Gabaix and Landier provided the solution for a CEO pay in terms of the size of a reference firm as well as the CEO's firm. The most relevant equation for our study is expressed in terms of the effective size of firm as following[1]:

$$w = D_* \widehat{S_*}^{\alpha} \hat{S}^{\beta} \qquad (6)$$

where w is CEO pay, $\hat{S}$ and $\widehat{S_*}$ are the effective size of the CEO's firm and a reference firm, respectively, and α and β are positive constants. D_* is a function of the marginal talent of CEO, $T'(n_*)$ of the reference firm and the size of the reference firm. In all equations, the subscript * indicates attributes for a reference firm.

The effective size of a firm in Gabaix and Landier's model is a function of the sensitivity of the firm to CEO talent and the nominal size of the firm. We extend this concept further; CEO may be able to reach a greater portion of her firm if her firm is more integrated through its IT system. In other words, we hypothesize that the effective size (that CEO can affect) increases as a firm is more integrated through an information technology (IT) system. This hypothesis reflects that IT reduces, to name a few, the cost of communication between top managers and employees, the cost of implementing new business processes, and the cost of monitoring employee performances. For example, a large retailer such as Wal-Mart has adopted an enterprise IT system and the inventories and sales data from

[1] This is the equation (25) of Proposition 3 on p.85 by Gabaix and Landier.

approximately 4,000 retail stores in the USA alone can be accessed and analyzed in its headquarter on real-time. Therefore, the effective size that top managers in its headquarter can reach has been widened with the centralized IT system allowing the global access to the data only local managers were accessible to in the past without such a centralized IT system. Therefore, we assume that the effective size is an increasing function of both IT and nominal size.

$$\hat{S} = cI^{\delta}S \tag{7}$$

where c is a constant, I is the IT intensity, δ is a constant, and S is the nominal size of the firm.

The nominal size can be of various measures; they usually include employee numbers, sales, market capitalization, and assets. Following Gabaix and Landier's agnostic approaches, we used employee numbers, physical capital assets, and market capitalization as the nominal size and empirically chose the best proxy. As shown in the result section, the market capitalization turned out to be the best proxy for the nominal size. This is also what Gabaix and Landier found. The equations (6) and (7) yield that:

$$w = D_* c_*^{\alpha} I_*^{\alpha\delta} S_*^{\alpha} c^{\beta} I^{\beta\delta} S^{\beta} = A_*^{\mu} I_*^{\varepsilon} S_*^{\alpha} c^{\beta} I^{\rho} S^{\beta} \tag{8}$$

where $A_* = D_* c_*$, and μ, ε, and ρ are constants.

The resulting empirically testable equation is the following:

$$\ln(w_{i,t}) = \beta_1 + \beta_2 \ln(A_{*t-1}) + \beta_3 \ln(I_{*t-1}) + \beta_4 \ln(S_{*t-1}) + \beta_5 \ln(I_{i,t-1}) + \beta_6 \ln(S_{i,t-1}) \tag{9}$$

where *i* and *t* indicate an index for firm and time, respectively. This equation implies that the compensation for a CEO this year ($w_{i,t}$) is determined by the effective size of a reference company (I_{*t-1} and S_{*t-1}) as well as the CEO's firm ($I_{i,t-1}$ and $S_{i,t-1}$) in the previous year along with other characteristics associated with the reference company (A_{*t-1}). This time lag lessens the potential simultaneity problem between CEO pay and the effective firm size.

We tested this model in both firm-level and industry-level. The concept of the model lies at firm-level; however, as we argue that an IT-intensive firm may increase its effective size and thus the marginal productivity of its CEO but we do not have firm-level but industry-level IT intensity data, the industry level analysis may be more consistent with our measures of IT intensity. Therefore, we present both firm-level analysis more consistent with our model and industry-level analysis more consistent with our empirical measures.

A_* is a variable relevant to a reference company such as the marginal talent of CEO of the reference company and the sensitivity of the reference firm to its CEO talent (not captured by the effective size). This measure captures business environments that the CEO's firm of interest is under, on the assumption that the CEO's firm would face a similar environment as its reference firm. For example, a firm in a highly-competitive industry may reward its CEO's talent more because it takes more talent to win over the competition; a firm in the industry where more educated workers belong may also reward its CEO because it needs a CEO to understand the complexities of the tasks that the workers of his firm may have to deal with. Therefore, we used two measures for A_* which can capture the business environment to some degree: industry turbulence and industry-median worker income. To compare our results with Gabaix and Landier's results, we conducted our analysis with and without the variable, A_* as Gabaix and Landier assumed that A_* may be the same for all firms and dropped it in their empirical analysis. In both cases, IT intensity was statistically significant.

In our test, we used IT intensity, defined as the ratio of IT capital stock to the total capital stock of plant, equipment and IT capital, as the IT variable. I_{*t-1} is IT intensity for a reference company in year t-1. Whether we choose a median-sized firm or the 250th-ranked firm[2] in year t-1 as a reference firm, I_{*t-1} depends mostly on the year variable as IT intensity has substantially grown as time. The variation in IT intensity over time for a reference firm was not very different from the variation in IT intensity over time for the whole economy. Therefore, we used the IT intensity for the whole economy in year t-1 for I_{*t-1}except the models with fixed year effect. In the models with fixed year effect, the IT intensity for the whole economy was not included because there is no variation within a fixed year. The model with fixed year effect resolves the issue not whether the difference in the firm-level IT intensity explains the differences in CEO pay within an industry at a given year, but whether the differences in CEO

[2] The 250th-ranked firm was a reference firm in Gabaix and Landier's empirical analysis.

pay for the same sized firm across industry are explained by the differences in the industry-level IT intensity at a given year.

We used industry-level IT as our measure of $I_{i,t-1}$ in the equation (9). This stems from two reasons, one practical and the other theoretical. The practical reason is that high quality firm-level IT data does not exist for the full period we seek to consider. Accordingly, industry-level IT intensity can serve as a noisy measure of firm-level IT intensity. The second reason for this approach is that using the industry-level IT intensity can mitigate a potential endogeneity problem; suppose that for some reason highly paid CEOs tend to spend more on IT investments in their own firms, leading to a positive correlation between CEO pay and firm-level IT intensity. By taking the IT intensity at the industry level and by also using the previous year's data as a covariate in the regression to determine the current year's CEO pay at firm level, the endogeneity problems are reduced.

The variables, S_{*t-1} and $S_{i,t-1}$, are the nominal size of a reference company and the CEO's firm of interest in the previous year, respectively. For firm-level analysis, we chose the 250th-ranked firm in the previous year as the reference firm following Gabaix and Landier's model. For industry-level analysis, there is no difference between a reference firm and a firm of interest and we treat those as one industry size variable. We used the total labor cost and the total net value of physical capital in each industry in the previous year for the industry size variable (S_{*t-1} and $S_{i,t-1}$).

For the firm-level analysis, two models, one using employee number and net value of physical capital and the other using market capitalization, were compared to select a better proxy for firm size in the context of CEO pay. As shown in Table 1, the market capitalization captured the firm size better, consistent with Gabaix and Landier's result. For all other models at firm level, we used the market capitalization as the firm size variable.

For the industry-level analysis, the model was assessed in three ways. First, all of the CEO compensations available from the data source were regressed only on the firm size variables (labor cost and net value of physical capital). Then, IT intensity variables were added as in the equation (9). Thirdly, other potential variables, median worker wage and industry turbulence, which may concur with IT intensity, were included to check the robustness of our model. Models with fixed effects of industry, firm, and year were also examined.

It should be also noted that we excluded the IT-producing industries; computer software and hardware industries. Although the impact of CEO decisions and skills on the firm value in these industries is likely to be amplified due to IT as well, IT in these industries may affect many other aspects of their businesses in a different way. Therefore, the correlation of CEO pay with IT intensity in these computer industries may be very different from that in other industries merely using IT. To focus on our main points of the influence of IT usage on CEO pay, we excluded the IT-producing industries.[3]

Data Sources and Variables

IT intensity at industry level

We followed a method similar to one described in a previous study (Brynjolfsson et al. 2007) to estimate IT intensity at industry level. In summary, IT intensity was defined to be IT capital stock divided by the sum of Plant, Equipment and IT capital stock. The capital stock data for IT, Plant and Equipment are available from the Bureau of Economic Analysis's (BEA) "Tangible Wealth Survey" for 63 industry sectors at approximately three-digit NAICS level from 1947 to 2006. We used two variables for IT intensity; one is the IT intensity in the whole economy each year and the other is the IT intensity of each industry each year. As IT intensity is either at industry-level or at the whole economy, our firm-level analysis uses the industry-level IT intensity data.

[3] However, the inclusion of IT-producing industries does not change our main results.

CEO compensation and firm-level company data

We used two Compustat databases, *Industrial* and *Executives*, for the period from 1992 to 2006. Compustat provides commercially available databases for public companies. The Industrial database provides firm characteristics such as physical assets, employee numbers, common stock and sales, while the Executives database provides data on compensation of the top executives up to 13 from each company. The Executives database is compiled from proxy statements filed by the companies in compliance with Securities and Exchange Commission (SEC) regulations and covers S&P 1500 companies starting in 1992.

The CEO compensation, *w*, was the variable, *tdc1*, from Compustat Executives data set. The *tdc1* includes salary, bonus, other annual, restricted stock grants, LITP payouts, all other, and value of option grants. We selected companies with at least three executives included in the database.

For industry-level analysis, the compensation (tdc1) of CEO or three top executives from each firm was summed over each industry. As a size variable, we used two variables; one is the labor cost and the other is the physical capital. The labor cost of each industry was estimated by the total employee number of the selected companies in each industry multiplied by the median worker wage of the industry. The median worker wage of each industry was obtained from the Current Population Survey (CPS) as explained later.

For firm-level analysis, the firm size, *s*, was represented in two ways; one is the employee number and physical capital, the other is the market capitalization following Gabaix and Landier (2008). They reported that the market capitalization was the best proxy for firm size. It was calculated by the equation, *data199* x *abs(data25)* + *data6* – *data60* – *data74*, where *data199* is the share price of closing at fiscal year, *data25* is Common Shares Outstanding, *data6* is Total Assets, *data60* is Total Common Equity, and *data74* is Deferred Taxes. All nominal quantities were converted into 2000 dollars using the GDP deflator from the BEA.

Industry-level median worker's income

We used data from the Current Population Survey (CPS) to estimate the median worker's income for the period from 1992 to 2006. CPS is a monthly survey of about 50,000 households conducted by the Bureau of the Census for the Bureau of Labor Statistics. The survey provides data related to employment such as wage, industry and occupation and a variety of demographic characteristics such as age, marital status and education attainment. We used their wage data for fulltime workers, *incwage*, to estimate median workers' wage income in each industry each year. We also used their total income data, to be more comparable to CEO pay data which include bonuses and stock options as well as salaries, and compared its result with that using *incwage*. The results from both variables were very close and we report the result using *incwage*.

Industry Classification

A hybrid industry classification was created to merge the IT capital data from BEA and the median worker's wage income data from CPS. The resulting industry classification has 58 sectors as listed in the appendix, fewer than 63 sectors from BEA. The industry classification that CEO compensation and company data are based on is SIC and NAICS. The SIC and NAICS industry codes were, therefore, converted to our hybrid industry classification for the analysis. It should be noted that the industry classification used by Gabaix and Landiers (2008) shown in Table 2 is Fama-French industry classification (48 sectors), different from our industry classification (58 sectors). Excluding the observations with missing variables and firms in IT-producing industries, our data universe consisted of 2,507 firms, 20,087 observations, and 53 industry sectors over 15 years.

Results and Discussion

Firm-Level Analysis

For the firm-level analysis, the number of employees in the firm and firm's physical capital (net property, plant, and equipment) were used as size variables in the model 1-1A. The IT variables were statistically and economically significant. Following Gabaix and Landier (2008), we then used market capitalization as a size variable as in the model 1-1B.

Inclusion of IT variables in the model changed the coefficient associated with the reference firm size (that is, the size of the 250th-ranked firm). We were able to replicate the findings of Gabaix and Landier when we used their model (the result was not shown). However, when we added IT to the model, the coefficient associated with the size of the 250th-ranked firm dropped to half of the value in the earlier model (model 1-1B in Table 1). The effect of the size of the reference firm seems to be partly captured by the IT intensity in the whole economy. Moreover, the overall IT intensity of the whole economy is as important as the firm size in determining the CEO pay as shown in each of the models of Table 1.

In the models with fixed industry effect or fixed firm effect (1-2 and 1-3), IT intensity of the firm's industry remains positive, but is not statistically significant. This is understandable, since fixed effects undoubtedly over-control for the effects of IT that are constant within a firm or industry. For any given year, however, the CEO pay difference is explained by the industry difference in IT intensity as shown in model 1-4; each 1% change in IT intensity is correlated with a bit more than 0.1% change in CEO pay across firms.

Robustness Check of Firm-Level Analysis

We further checked the robustness of the model by including two potential variables which may have the same trend with IT intensity. This is to relax Gabaix and Landier's assumption that A_* in Eqn (9) is the same across firms. We argue that A_* may be the same across firms in their industry but different from firms in other industries. Therefore, we used industry-level measures for two variables. The first was median worker wage. IT-intense industries may be industries to use more highly educated employees and pay their employees more. Accordingly, CEOs in those industries may be paid more. The second was industry turbulence. Throughout all models in Table 2, the IT intensity variables positive and is usually statistically significant.

Median worker wage

An unexpected result was that, when IT and the other controls are included, the median worker wage was actually negatively correlated with CEO pay. This result is not inconsistent with our hypothesis that problem solving is concentrated to a few superstars as IT becomes more prevalent, leading to a higher pay to the superstars and perhaps less responsibility and pay for the median worker in firms that allocate decision-making in this way. This result should be, however, taken with caution. Our data of median worker income is at industry level including small firms while CEO pay is at firm level from S&P 1500 firms. Therefore, our result doesn't mean that CEO compensation is negatively correlated with median worker compensation in the same firm or a firm of similar size. It is well-known that large firms tend to pay their employees higher salary than smaller firms. However, using the income data of median workers only working for the subset of relatively large firms do not change our results of IT being significantly correlated with CEO pay (results are not shown), suggesting that IT increases the pay for CEO or a few superstars much more highly than median workers even among large firms.

Industry Turbulence

Industry turbulence was also a significant variable to determine CEO pay in these specifications, in similar magnitude to the industry-level IT intensity (Table 2). This result is consistent with the explanation that the highly competitive business environment in recent decades may have increased CEO pay Dow and Raposo 2005. As with firm size itself, the increase in industry turbulence, however, may also be caused in part by high IT intensity. In fact, this has been specifically argued by some researchers Brynjolfsson et al. 2007: IT-intense industries may be highly turbulent industries and IT intensity may allow the industry turbulence. More turbulent industries may benefit more from highly talented CEOs and thus pay them more. Thus, our coefficients may actually underestimate the role of IT. The full effect of IT may be larger than is implied by the coefficient of IT intensity in these models, since a part of IT's effect may work through changes in industry turbulence and nominal firm size.

Nominal Firm Size and IT intensity

Our model views that IT widens top managers' reach inside their firms of a given size. However, IT can also play an important role in changing firm size. Taking theories of firms on transaction or coordination costs (Coase, 1937; Williamson, 1973, 1981), many researchers have proposed that IT advancement would change firm size. IT can reduce transaction cost between firms, favoring the market over firms and leading to smaller firms (i.e., Brynjolfsson et al. 1994; Malone et al. 1987). On the other hand, IT can reduce coordination cost within a firm and lead to a larger firm (i.e., Zhu 2004; Armour and Teece 1978). Some researchers also reported that IT may lead to smaller firms in manufacturing and larger firms in retail and service sectors (Wood et al. 2008). Other research results on the effect of IT and firm size showed that large firms in IT-intensive industries tend to become larger, suggesting that IT may increase firm size of large firms (Saunders 2008). The role of IT as well as other factors in determining firm size is beyond the scope of this paper. It is, however, worth mentioning how the role of IT in changing firm size can change our result. In case that IT leads to larger firm, IT has an indirect impact on CEO pay increase by increasing firm size while in our model IT has a direct impact on CEO impact by increasing CEO reach within her firm. Our estimate only captures the direct impact and may be underestimated. In case that IT leads to smaller firms, IT may decrease CEO pay by decreasing the firm size and as a result the CEO pay increase may be lowered. However, if IT in large firms leads to the increase in their nominal firm size for most sectors, as in Saunders' study (2008), the nominal size of the firms in our study, S&P 1500 firms, may have increased due to IT. Then IT may increase the nominal firm size as well as the effective firm size and our study may have underestimated the IT effect on CEO pay.

The basics of our model are to take the nominal or effective firm size as exogenous from CEO pay. However, it is possible that the growth of the firm size and CEO pay may reflect a positive feedback cycle. For example, our model can be read that the 2nd-ranked CEO is match to run the 2nd largest firm as measured by *effective* size (reflecting both IT and the nominal size), in a competitive equilibrium at t=1. If the CEO grows the firm to become the 1st-ranked largest firm in effective size by the end of t=1; then she will be managing the largest firm at t=2. Thus, the CEO who managed the 2nd-ranked largest firm in effective size at t=1 become most highly paid at t=2.

Interestingly, while CEO pay has been found to be correlated with nominal firm size after 1970, no correlation was found for earlier years (Frydman and Saks 2007). Our result is consistent with this fact as well. The integration of data within firm has become possible with IT advancement only for the last few decades. A case of Johnson and Johnson (Ross 1995) illustrates an example of increase in the effective firm size upon the introduction of IT system. Johnson & Johnson, founded in 1886, had a long history of managing its operating companies as independent business, embracing the decentralized management approach as a path to increased flexibility, accountability and creativity. Each operating company had its own marketing and sales units and its executives were compensated based on the performance of their company, not the corporation as a whole. Problems with the decentralized management approach surfaced when customers tried to limit their vendor interactions; in certain cases one customer got calls from up to 18 representatives from different J&J companies. Over time, Johnson and Johnson started introducing various structures to increase inter-company cooperation and a more coherent management practice. A business strategy to achieve the coherent management practice over the whole corporation was to build and introduce a corporate IT system to share data across business units and practice cross-company cooperation among 160 operating companies. In other words, the effective size of Johnson and Johnson that the corporate headquarters reached before the introduction of IT system could be much smaller than that after the introduction of IT system while their nominal size may seem unchanged. Therefore, CEO pay may seem poorly correlated with the nominal firm size when the nominal firm size does not accurately reflect its effective size.

Generality of Managerial Skills and IT

Information technology (IT) may be correlated with the increasing generality of the required managerial skills. Managerial decisions are increasingly becoming based on data more than experience. The data-based decision-making practices are likely to make the managerial skills transferrable across firms and industries, increasing the generality of the required managerial skill. For instance, Gary Loveman, CEO of Harrah's Entertainment Corp. successfully transformed that company by bringing to bear a set of analytical methods and "rocket scientists" from outside the industry (Becker, 2003). He had no special knowledge of that industry, and has said that he could just as easily have brought the same techniques to any other industry.[4] There is some evidence that firms practicing data-driven decision-making tend to pay their CEOs more (Brynjolfsson, Hitt, and Kim, 2010). This is consistent with the arguments that the increase in CEO pay may be due to the increased generality of the required managerial skills (e.g., Frydman, 2005; Murphy and Jabojnick, 2007). Our empirical evidence does not exclude this explanation. On the contrary, IT may increase the effective size of firm and such firms may have more incentives to practice the data-driven decision-making as data-based business practices can be scaled up more easily. The data-driven decision-making practices may increase the generality of the required CEO skills.

Industry-Level Analysis

As our IT investment data were at industry-level, our second analysis was performed at industry-level to be consistent with the resolution of our IT intensity data. The industry-level analysis, however, is not based on the model matching the largest firm to Model 3-1B, where two variables for IT intensity, one the IT intensity of the whole economy and the other IT intensity of each industry, were included. It shows a statistically significant correlation of IT intensity with CEO pay; 0.51 for the IT intensity in the whole economy and 0.31 for her industry IT intensity.

With the fixed industry effect (3-2A and 3-2B), the increase in CEO pay over time was picked up most significantly by the increase of IT intensity in the whole economy over time. The coefficient associated with IT intensity of each industry was still significant but lower than that in the model without fixed effects.

The next two models, 3-3A and 3-3B, included year dummy variable, comparing CEO compensations across industries in a given year. An industry with 1% higher IT intensity in the previous year tends to pay its CEOs by 0.3% higher than those in other industries. The models with both time dummies and industry fixed effects, 3-4A and 3-4B, the coefficient associated with IT intensity is still significant at 5% significance level. This implies that, in a given year and within an industry, a 1% increase in IT intensity in the previous year is correlated with a 0.15% increase in CEO compensation, a quantity that is significant both statistically and economically.

To check the robustness of our model, we included industry turbulence as another covariate as in the earlier firm-level analysis. Industry turbulence was statistically significant as shown in all models in Table 4. The coefficient of industry turbulence increase more than a factor of two when the industry fixed effect is not included (model 4-1 and 4-2 in table 4). Nonetheless, inclusion of industry turbulence did not qualitatively change our results and all the coefficients associated with IT intensity remained significant at 5% level (Table 4). Moreover, the magnitude of the coefficient associated with IT intensity of the whole economy increased, and that of the coefficient associated with industry-level IT intensity remained the same (0.18 in model 3-2B and 0.16 in model 4-2; 0.15 in model 3-4B and 0.14 in model 4-4).

Our model isn't necessarily limited only to the CEO. As the IT facilitates information flows and process replication within a firm, not only CEOs but also other executives and "superstars" may find their decisions have more impact on the firm performance. In turn, this should be reflected in their compensation as well. In the models shown in Table 5, we selected top three executives from each firm, summed their compensation over each industry, and regressed them on size, IT, and industry turbulence. The results were similar to the result with only CEO compensation (Table 5). The coefficient associated with the IT intensity of the whole economy with or without industry fixed effect was 0.79 or 0.63, respectively. The coefficient associated with IT intensity of industry was also similar to that in the model only for CEO compensation.

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[4] Presentation at Erik Brynjolfsson's "Economics of Information" class at MIT, October, 2009.

Conclusion

This paper examined the importance of information technology (IT) in CEO compensation. IT intensity was generally the most significant variable explaining CEO pay. We reason that IT intensity allows a more integration of a firm and increases the effective size of the firm that a top manager like CEO can reach and control. Therefore, the firm's CEO pay, the marginal productivity of the firm's CEO, would be based on the effective size of the firm, a function of not only its nominal size but also its IT intensity. We argue that, in equilibrium, the CEO of the largest firm in terms of effective size will tend to be paid the most. As effective firm size grows, reflecting improvements in IT, so will the average pay of CEOs and other top executives. Our model was robust with inclusion of other potential variables such as median worker wage and industry turbulence.

While the correlations we find are fairly robust, it is also possible that IT intensity affects CEO pay through other mechanisms. For instance, IT may have led to managerial decisions that are increasingly based on data rather than experience and intuition. These data-driven decision-making practices have standardized skill sets and require less firm-specific skills than they would if the CEO's decisions were mostly based on her domain knowledge and experience. This is consistent with the result by Frydman (2005) that CEO skills have become less firm-specific. However, she concludes her paper by noting "An important question remains unanswered: what has caused the change in the type of skills over time?" One answer may be the increased power and ubiquity of digital technologies. In any event, the finding of such a strong and large correlation between relative CEO pay and IT intensity is both novel and economically significant.

Our findings have important implications for how we think about the growth in CEO pay and inequality. If the underlying drivers relate to changes in the way technology propagates instructions and innovations within the firm, then firms may wish to adjust their recruiting, hiring and retention policies as well as their IT investments and architectures. Similarly, policy-makers will want to craft tax and labor policies that can mitigate inequality while preserving efficiencies in talent matching and executive decision-making as much as possible. To the extent that we expect continuing advances in the power of IT to amplify and propagate decisions, the relationships we uncover in this paper can likewise be expected to continue and even grow. This could portend a world with increased productivity growth as innovations are ever replicated with ever more fidelity and speed throughout the firm, but also even more "superstar" pay for top executive and an even more skewed distribution of income.

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Table 1. Firm-Level Analysis of CEO Pay I[5]					
	Log(CEO Compensation)$_{i,t}$				
	(1-1A)	(1-1B)	(1-2)	(1-3)	(1-4)
Log(Employee Number, $S_{i,t}$)	0.15*** (0.01)				
Log(Physical Capital, $S_{i,t}$)	0.18*** (0.01)				
Log(Market Capitalization, $S_{i,t-1}$)		0.42*** (0.01)	0.44*** (0.004)	0.35*** (0.009)	0.42*** (0.004)
Log(250th-ranked Firm Market Capitalization in the whole economy, S_{*t-1})		0.28*** (0.05)	0.25*** (0.05)	0.37*** (0.04)	
Log(IT intensity of the whole economy, I_{*t-1})	1.21*** (0.05)	0.40*** (0.10)	0.45*** (0.10)	0.37*** (0.09)	
Log(IT intensity of their industry, $I_{i,t-1}$)	0.25*** (0.02)	0.12*** (0.01)	0.04 (0.03)	0.03 (0.03)	0.12*** (0.005)
Industry Fixed Effect	No	No	Yes	No	No
Firm Fixed Effect	No	No	No	Yes	No
Year Fixed Effect	No	No	No	No	Yes
Number of Firms	2507	2507	2507	2507	2507
Number of Industries	53	53	53	53	53
Observations	20087	20087	20087	20087	20087
Adjusted R-squared	0.32	0.46	0.50	0.68	0.46

[5] ***, **, *, and ~ indicate 0.1%, 1%, 5%, and 10% level of significance, respectively.

Table 2. Firm-Level Analysis of CEO Pay II				
	Log(CEO Compensation)$_{i,t}$			
	(2-1)	(2-2)	(2-3)	(2-4)
Log(Market Capitalization, $S_{i,t-1}$)	0.43*** (0.007)	0.44*** (0.004)	0.35*** (0.009)	0.43*** (0.003)
Log(250th-ranked Firm Market Capitalization, S_{*t-1})	0.39*** (0.05)	0.35*** (0.05)	0.44*** (0.04)	
Log(IT intensity of the whole economy, I_{*t-1})	0.26~ (0.10)	0.29** (0.11)	0.26** (0.09)	
Log(IT intensity of their industry, $I_{i,t-1}$)	0.10*** (0.01)	0.03 (0.03)	0.02 (0.03)	0.10*** (0.006)
Log(Industry turbulence, A_{*t-1})	0.08*** (0.01)	0.09*** (0.02)	0.07*** (0.01)	0.08*** (0.006)
Log(median worker wage in their industry, A_{*t-1})	-0.36*** (0.04)	-0.12~ (0.07)	-0.08 (0.06)	-0.36*** (0.02)
Industry Fixed Effect	No	Yes	No	No
Firm Fixed Effect	No	No	Yes	No
Year Fixed Effect	No	No	No	Yes
Number of Firms	2507	2507	2507	2507
Number of Industries	53	53	53	53
Observations	20087	20087	20087	20087
Adjusted R-squared	0.48	0.51	0.68	0.48

Table 3. Industry-Level Analysis of CEO Pay[6]								
	$\text{Log}(\sum_i \text{CEO Compensation})_{I,t}$							
	(3-1A)	(3-1B)	(3-2A)	(3-2B)	(3-3A)	(3-3B)	(3-4A)	(3-4B)
$\text{Log}(\text{Labor Cost})_{I,t}$	0.77*** (0.08)	0.54*** (0.08)	0.67*** (0.06)	0.51*** (0.06)	0.77*** (0.03)	0.54*** (0.04)	0.49*** (0.06)	0.49*** (0.06)
$\text{Log}(\sum_i \text{Physical Capital})_{I,t}$	0.05 (0.07)	0.19** (0.07)	0.003 (0.06)	0.01 (0.06)	0.05~ (0.03)	0.19*** (0.03)	0.01 (0.06)	0.004 (0.06)
$\text{Log}(\text{IT intensity in the whole economy})_{t-1}$		0.51** (0.20)		0.66*** (0.12)				
$\text{Log}(\text{IT intensity})_{I,\,t-1}$		0.31*** (0.08)		0.18* (0.07)		0.31*** (0.04)		0.15* (0.07)
Industry Fixed Effect	No	No	Yes	Yes	No	No	Yes	Yes
Year Fixed Effect	No	No	No	No	Yes	Yes	Yes	Yes
Number of Firms	2507	2507	2507	2507	2507	2507	2507	2507
Number of Industries	53	53	53	53	53	53	53	53
Observations	679	679	679	679	679	679	679	679
Adjusted R-squared	0.69	0.73	0.90	0.91	0.70	0.73	0.92	0.92

[6] Labor cost $=\sum_i (\text{employee number}) \times \text{median worker salary in her industry})_{I,t}$, $\sum_i (\text{Physical Capital})_{I,t} = \sum_i (\text{net of property, plant, and equipment})_{I,t}$. The subscript i, e, I, and t indicate firm, executives, industry, and year, respectively.

Table 4. Robust Check for Industry-Level Analysis				
	Log($\sum_i$ CEO Compensation)$_{I,t}$			
	(4-1)	(4-2)	(4-3)	(4-4)
Log(Labor Cost)$_{I,t}$	0.37*** (0.06)	0.54*** (0.06)	0.36*** (0.03)	0.50*** (0.06)
Log($\sum_i$ Physical Capital)$_{I,t}$	0.20*** (0.05)	0.004 (0.06)	0.21*** (0.02)	0.008 (0.06)
Log(IT intensity in the whole economy)$_{t-1}$	0.86*** (0.19)	0.68*** (0.12)		
Log(IT intensity)$_{I, t-1}$	0.13* (0.06)	0.16* (0.07)	0.13*** (0.03)	0.14* (0.07)
Log(Industry turbulence)$_{I, t-1}$	0.49*** (0.06)	0.19*** (0.04)	0.50*** (0.02)	0.16*** (0.05)
Industry Fixed Effect	No	Yes	No	Yes
Year Fixed Effect	No	No	Yes	Yes
Number of Firms	2507	2507	2507	2507
Number of Industries	53	53	53	53
Observations	679	679	679	679
Adjusted R-squared	0.83	0.91	0.83	0.92

Table 5. Industry-Level Analysis of Top 3 Executives' Pay				
	Log($\sum_i \sum_e$ Top 3 Executives' Compensation)$_{I,t}$			
	(5-1)	(5-2)	(5-3)	(5-4)
Log(Labor Cost)$_{I,t}$	0.35*** (0.05)	0.51*** (0.06)	0.35*** (0.03)	0.47*** (0.06)
Log($\sum_f$ physical capital)$_{I,t}$	0.20*** (0.05)	0.02 (0.05)	0.20*** (0.02)	0.02 (0.05)
Log(IT intensity in the whole economy)$_{t-1}$	0.79*** (0.18)	0.63*** (0.11)		
Log(IT intensity)$_{I, t-1}$	0.13* (0.06)	0.14* (0.06)	0.12*** (0.03)	0.12* (0.06)
Log(Industry turbulence) $_{I, t-1}$	0.50*** (0.05)	0.17*** (0.04)	0.51*** (0.02)	0.13*** (0.04)
Industry Fixed Effect	No	Yes	No	Yes
Year Fixed Effect	No	No	Yes	Yes
Number of Firms	2507	2507	2507	2507
Number of Industries	53	53	53	53
Observations	679	679	679	679
Adjusted R-squared	0.84	0.93	0.85	0.93

Table 6. CEO pay and the ratio of CEO pay to average employee wage after controlling for the average employee's human capital. The importance of education and the percentage of employees using e-mail or PC were used to control for employee human capital.

	Ln(CEO pay)	Ln(CEO pay/Average Employee's Wage)		
		Industry-average employee wage	Firm-level employee wage	Industry-average employee wage in selected industries
Ln(Employee)	0.254***	0.328***	0.243**	0.264***
	(0.04)	(0.05)	(0.12)	(0.07)
Data-driven decision-making (Data)	0.177***	0.195**	0.448**	0.250**
	(0.05)	(0.08)	(0.19)	(0.10)
Consistency of business practices (Consistency)	-0.0256	-0.0607	0.0159	-0.105
	(0.06)	(0.07)	(0.20)	(0.11)
Data x Consistency	0.0888**	0.0866	0.269**	0.446***
	(0.04)	(0.06)	(0.13)	(0.12)
Importance of Typical Employee's Education	0.153***	0.016	0.0107	-0.00743
	(0.06)	(0.06)	(0.11)	(0.09)
Ln(% of Employees using PC/e-mail)	0.045	0.0266	0.0361	0.261
	(0.11)	(0.13)	(0.43)	(0.20)
Constant	7.457***	3.219***	4.414**	2.423**
	(0.52)	(0.56)	(2.12)	(0.92)
Industry and Year Control	Yes	Yes	Yes	Yes
Number of Firms	161	161	24	45
Observations	683	683	99	192
R-squared	0.29	0.274	0.608	0.5
Robust standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

System of equations

$$Ln(Sales)_{it} = \beta_0 + \beta_1\, Ln(Material)_{it} + \beta_2\, Ln(Physical\ Capital)_{it} + \beta_3\, Ln(IT\ Labor)_{it} + \beta_4\, Ln(Non\text{-}IT\ Labor)_{it} + \beta_5\, (DDD)_i + Other\ controls + u_{it}$$

$$Ln(CEO\ pay)_{it} = \delta_0 + \delta_1\, Ln(Sales) + \delta_1 (DDD)_i + Other\ controls + \varepsilon_{it}$$

$$= \alpha_0 + \alpha_1\, Ln(Material)_{it} + \alpha_2\, Ln(Physical\ Capital)_{it} + \alpha_3\, Ln(IT\ Labor)_{it} + \alpha_4\, Ln(Non\text{-}IT\ Labor)_{it} + \alpha_5\, (DDD)_i + Other\ controls + v_{it}$$

Table 7. Correlation between CEO pay and Data-driven decision-making

	Ln (CEO Pay)	Ln (Sales)
Ln(Sales)	0.467***(0.047)	

Ln (Material)		0.474*** (0.047)
Ln (Physical Capital)		0.112*** (0.023)
Ln (Non-IT Employee)		0.242*** (0.036)
Ln (IT Employee)		0.075*** (0.028)
DDD	0.108* (0.056)	0.041* (0.023)
Importance of Education		0.020 (0.027)
Ln (% of Employees using PC/Emails)		0.057 (0.036)
Ln (Avg. Employee Wage)	0.016 (0.07)	
Number of Observations	498	498
Number of Firms	141	141