

Enterprise System Productivity and Complementary Organizational Practices

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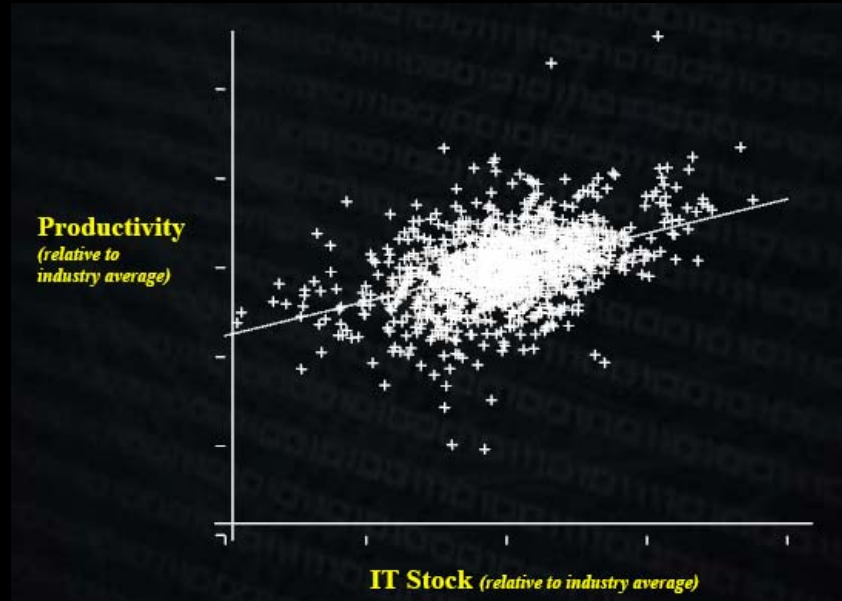
In collaboration with Sinan Aral and Erik Brynjolfsson

Research Goals

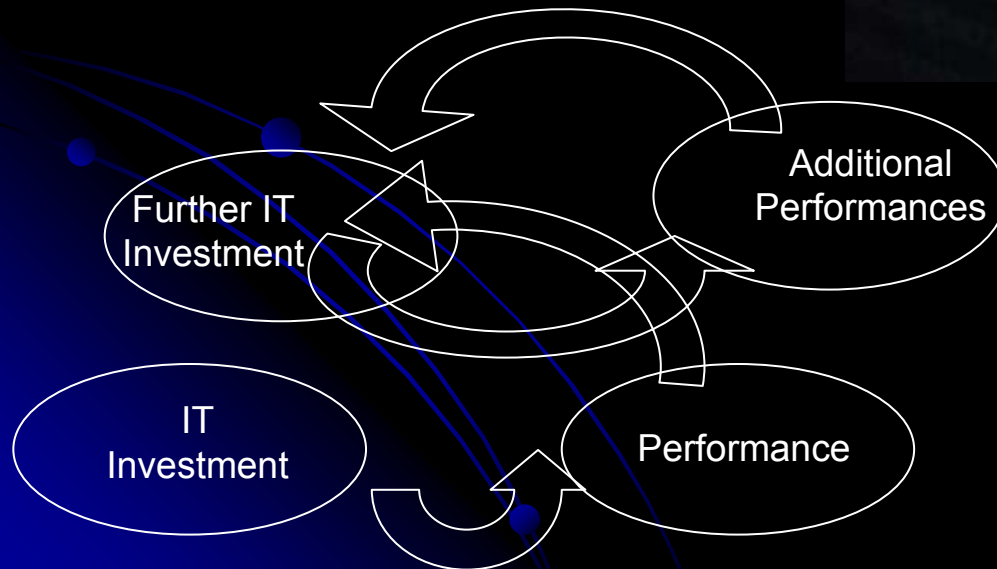
- Information technology, or IT, intensive firms are more productive
- How Enterprise Resource Planning system (ERP) impacts productivity
 - Specific business process
 - Organizational practices
 - Intangible investments

IT Productivity Research

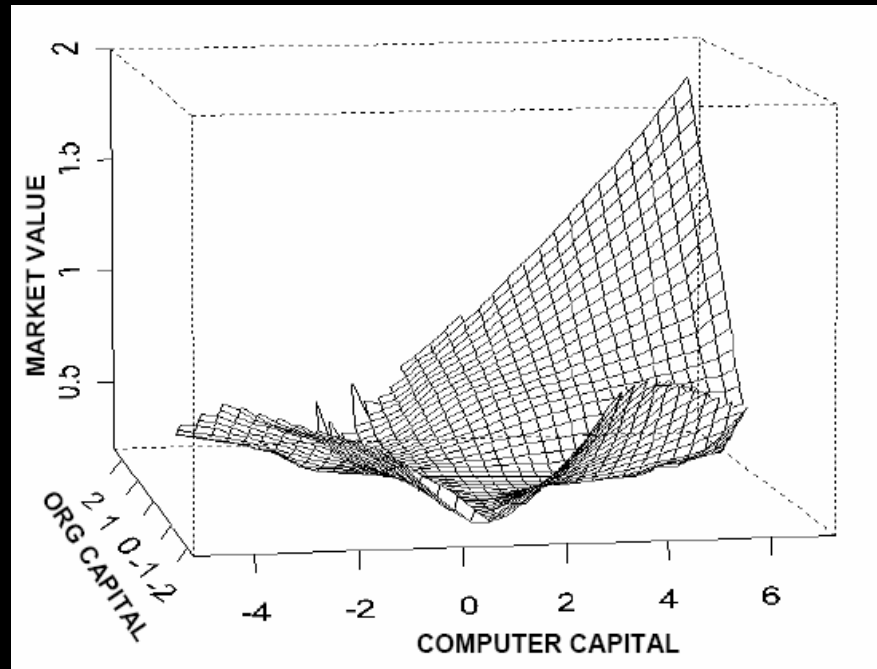
Graph 1. IT Stock and Productivity



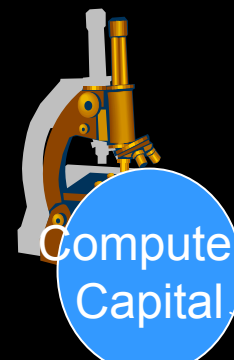
Graph 2. Virtuous Cycle



What Drives the Virtuous Cycle?



Human
Capital
Management
Practices



ERP
HCM
Modules


What Enables the Virtuous Cycle?

- Strategy: Detailed examination of business processes, organizational structures, and intangible assets.
- Method:
 - Data on enterprise systems investments
 - Detailed survey of organizational characteristics
- Goal: Identify critical complementarities
 - What processes, structures and intangibles improve returns?
 - What characteristics complement which systems?
 - What can firms do to maximize their returns?

Enterprise Resource Planning

- ERP has many classes of modules
 - Firms can choose to adopt HCM module.
- HCM modules can help HR work efficiently and effectively.
 - Provide more and accurate information at a lower cost.
 - Quickly update employee information to managers.
 - Lower the cost of HR transactions.
 - Centralize certain functions for shared services.

Human Capital Management (HCM) Practices

- Incentive Schemes
 - Pay for performance
 - Process to allow effective monitoring
 - Changes in compensation in response to monitoring
 - Recruiting—Search for talent
 - Training and Skill Development
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Incentive Systems—Moral Hazard

- Moral Hazard (MH)
 - The problem of asymmetric information.
 - A trade-off between incentives and insurance.
- To avoid MH, it is important for HCM policy and practices to
 - Align performance with pay
 - Reward when performing well, punish if performing poorly
 - Monitor effort and performances
 - Ensure that a worker's success is not a fluke

Moral Hazard — Model

- Employer, risk neutral
 - $\max \{E[q-w]\}$
 - q : output produced
 - w : wage paid
- Output: $q = a + \varepsilon_1$
- Agent is risk averse, has cost function
$$\Phi(a) = \frac{1}{2} ca^2$$
- Principal sees a signal s that approximates effort:
$$s = a + \varepsilon_2$$
- Suppose linear contracts: $w = t + b_1q + b_2s$
 - t is the fixed compensation level
 - b_1, b_2 are the variable performance-related component

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} = N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 0 & \sigma_1^2 \\ \sigma_2^2 & 0 \end{pmatrix}\right)$$

Moral Hazard — Model

principal:

$$\max_{t,s} E(q - w)$$

such that

$$E(e^{-n(w-s(a))}) \geq u(\bar{w}) \quad (IR)$$

$$a \in \arg \max_a E[-e^{-\eta(w-\varphi(a))}] \quad (IC)$$

First Best Solution:

$$b_1^{FB} + b_2^{FB} = 1 \quad a^{FB} = \frac{1}{c}$$

Second Best Solution:

$$b_1^{SB} + b_2^{SB} = \frac{1}{1 + c\eta \frac{\sigma_1^2 \sigma_2^2}{\sigma_1^2 + \sigma_2^2}} \leq 1$$

$$a^{SB} = \frac{b_1^{SB} + b_2^{SB}}{c} \leq a^{FB}$$

as $\sigma_2^2 \rightarrow 0, b_2 \rightarrow 1, b_1 \rightarrow 0$, we also achieve the first best.

Profit

$$\begin{aligned} E[\pi] &= E[q - w] \\ &= \frac{b_1 + b_2}{c} - \frac{(b_1 + b_2)^2}{c} - t \end{aligned}$$

$$\frac{\partial E[\pi]^2}{\partial (b_1 + b_2) \partial \sigma_2^2} = -\frac{2}{c} [\sigma_1^2 + \sigma_2^2 + c\eta \sigma_1^2 \sigma_2^2 + \sigma_2^2 (1 + c\eta \sigma_1^2)] < 0$$

Monitoring effort (reducing σ_2^2) and incentives schemes
• $(b_1 + b_2)$ are complements.

Two ways monitoring effort affects profit

- 1st order effect: reduce fixed payment t .
- 2nd order effect: increase the power of incentives $b_1 + b_2$.

Moral Hazard

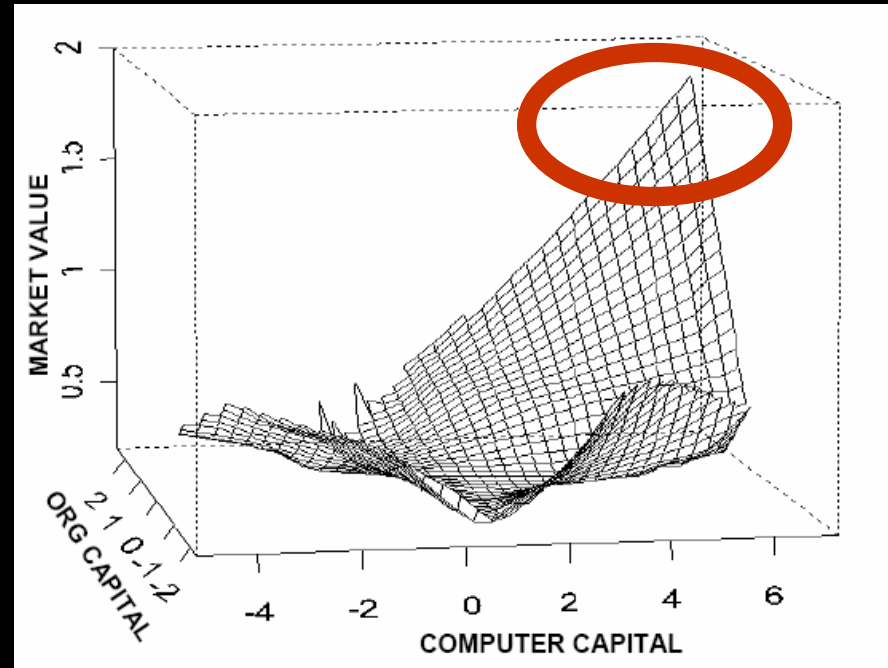
- ERP systems can be an effective monitoring tool that can decrease the magnitude of σ_2^2 , and improve profitability.
 - H1. Firms that explicitly allow effective monitoring experience greater productivity returns from ERP adoption than those that do not.
 - H2. Firms that adopt both policies of tying pay to performance and monitoring performances experience even greater productivity returns from ERP than just adopting monitoring alone.
 - H3. Firms that implements pay for performance without monitoring experience lower returns from ERP than those that do not.

Incentive Systems — Dynamic Contracting

- Imperfect knowledge about employees.
- Ability to incorporate newly gained information into contract may be optimal.
- Technologies lower the costs of generating information
- *H4. Firms that implements explicit policies to allow compensation change upon monitoring experience greater productivity returns from ERP than those that do not.*

Incentive System

- *H5. Firms that adopt all three incentive practices experience greater productivity returns from ERP than those that adopts any one alone.*



Recap — Incentive Systems

- Incentive systems

- *H1. Monitor* → ↑ *ERP return*

- *H2. Monitor + Pay for perf* → ↑↑ *ERP return*

- *H3. Pay for perf + no Monitor* → ↓ *ERP return*

- *H3. Allow change in contract* → ↑ *ERP return*

- *H4. Monitor + Pay for Perf + Allow change in contract* → ↑↑↑ *ERP return*

Recruiting—Search for Talent

- Search for talent is important during recruiting. It is important to
 - having a large pool of candidates
 - finding the right talent from the pool.
- ERP systems often lower the cost to finding candidates.
 - *H5. Firms that allow a comprehensive search and screening process for recruiting experience greater productivity returns from ERP than those that do not.*

Training and Skill Development

- ERP generates a lot of information
 - Workers need to know how to use ERP
 - Workers need to know how process new information.
- To process information generated by ERP, firms may need to intensify training and development effort.
 - *H6. Firms that explicitly allow for extensive training and skill development experience higher level of productivity returns from ERP than those that do not.*

Recap

- Search for Talent

- *H5. Search and screening* → ↑ *ERP return*

- Training and Skill Development

- *H6. Training* → ↑ *ERP return*

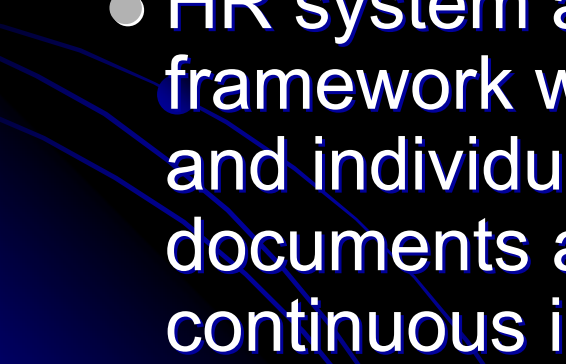
Current Data

- Generated 136 detailed survey questions about human capital management practices.
- Conducted survey in 2005.
- Collected 177 firm responses.
- Identified survey questions that corresponds to incentive systems, search for talent and skill development.

Sample Survey — Incentive Systems

- Pay for Performance: Contracts that tie pay to performance
 - (Rate on a scale of 1-6, 1 as being the least implemented and 6 being the most implemented.)
 - Compensation plans are designed to align pay with performance, and are linked to easily understood KPIs (e.g., corporate, divisional, organizational profitability)
 - Compensation plans are designed to support overall corporate business strategy as well as strategies of individual divisions/departments

Sample Survey — Incentive Systems

- Process to allow effective monitoring
 - Time and attendance system has automated analysis and reporting capabilities to analyze KPIs such as lost time, productivity, cost of absence, overtime or illness
 - HR system allows for a Balanced Scorecard framework which is integrated into department and individual performance appraisal documents and supports benchmarking and continuous improvement
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Sample Survey — Search for Talent and Skill Development

- Search for Talent

- Extensive pretesting of applicants performed to determine fit with job requirements

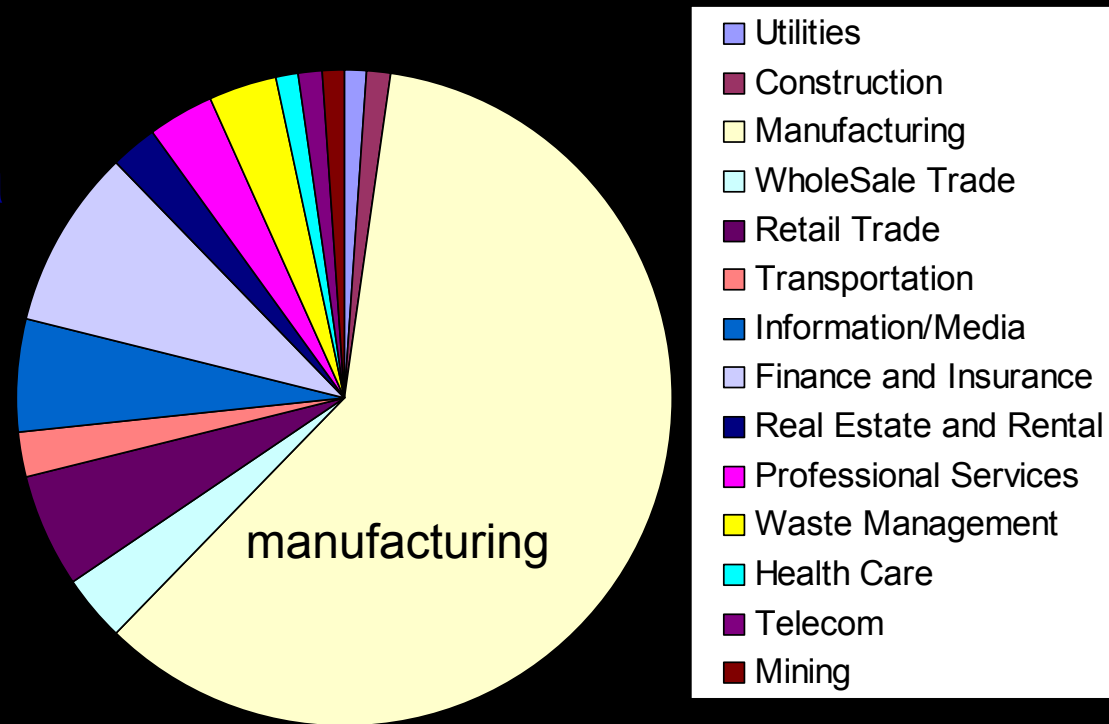
- Training and Skill Development

- Learning system has automated reports available to assess training effectiveness by correlating corporate KPIs with training results (e.g., sales increases with successful sales training completion, technical training with machine down time)
- Learning system comprises enhanced collaboration tools for online learning, such as instant messaging, chat or desktop sharing, and allows for mobile learning (at home/away from the office)

A Representative Sample Firms

- 177 firm responses
- Survey conducted in 2005
- 90 firms with performance data

Industry Distribution



Productivity & Performances

<u>Measure</u>	<u>Definition</u>	<u>Interpretation</u>
(1) Total Factor Productivity	Output, value added	Positive coefficient indicates contribution of IT factor to productivity
(2) Labor Productivity	Sales/# of Employees	High ratio indicates more productivity per employee
(3) Return on Assets	Pretax Income/Assets	High ratio indicates efficient operation of firm without regard to its financial structure
(4) Profit Margin	Pretax Income/Sales	High ratio indicates high profit generated by sales
(5) Debt to Equity	Debt/Equity	The higher the debt ratio, the more leveraged the firm
(6) Inventory Turnover	COGS/Inventory	High ratio indicates more efficient inventory management
(7) Asset Utilization	Sales/Assets	High ratio indicates high level of sales generated by total assets
(8) Collection Efficiency	Sales/Account Receivable	High ratio indicates effective management of customer payment

Empirical Methods

- Performance

$$\log(\text{Performance Numerator}) = \alpha + \beta_1 \log(\text{Performance Denominator}) + \beta_2 \text{ERP} + \beta_3 \text{HR} + \beta_4 \text{HRxERP} + \sum \text{Year} + \sum \text{Industry Controls} + \varepsilon$$

- Productivity

$$\log(\text{VA}) = \alpha + \beta_1 \log(K) + \beta_2 \log(L) + \beta_3 \text{ERP} + \beta_3 \text{HR} + \beta_3 \text{HRxERP} + \sum \text{Year} + \sum \text{Industry Controls} + \varepsilon$$

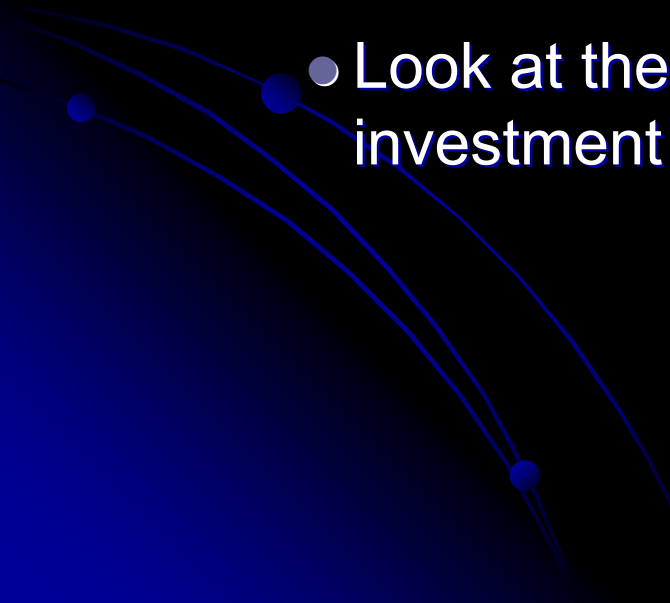
- Likelihood of ERP Investment

$$\ln \left[\frac{P(Y_i = 1)}{1 - P(Y_i = 1)} \right] = \alpha + \sum \beta X + \varepsilon$$

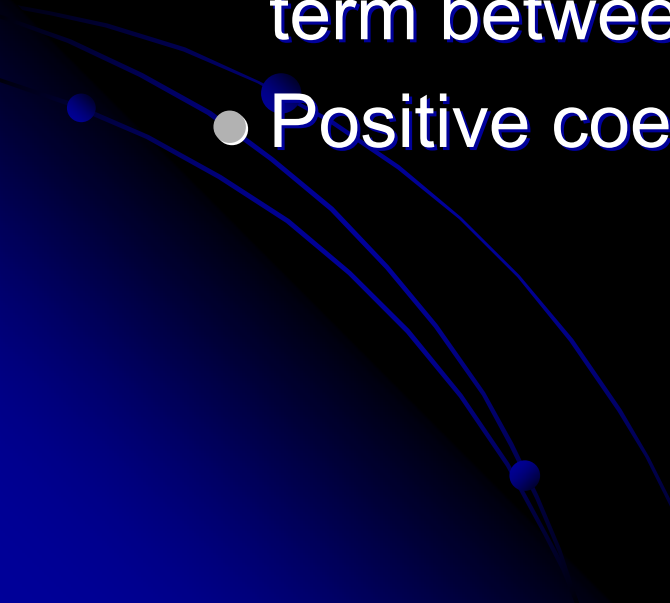
Identification

- There are several sources of endogeneity
 - ERP adoption may be endogenous
 - Follow Aral (2006) to separately estimate ERP installation and ERP go-live events
 - HR practices may be endogenous
 - Conduct the same survey at a different time
 - Having a panel data allows us to eliminate individual-firm invariant endogeneity

Future Data

- We need
 - Detailed adoption dates
 - Purchase, install, go-live dates
 - The same survey to be done at a different time
 - Look at the changes in HR practices and IT investment
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Next Steps

- Get the data
 - Refine models
 - Test the hypothesis
 - Determine the coefficients of the interaction term between ERP and HR variables
 - Positive coefficient: complementarity
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Thank You!

- Questions?

