Organizing product innovation: knowledge and incentives

Keld Laursen
Department of Innovation and Organizational Economics, Copenhagen Business School,
Kilevej 14a, 2000 Frederiksberg, Denmark
E-mail: kl.ino@cbs.dk,
http://www.druid.dk/laursen/

Outline

- Introduction
- What do we know about the use and effectiveness of incentives in firms – theory and evidence (Prendergast)
- Information technology and workplace organization, briefly (Bresnahan et al.)
- The effect of "new" work practices on innovative performance (Laursen/Foss)
- The risk-incentive trade-off: Performance Pay, Delegation, and Multitasking under Uncertainty and innovativeness (Foss/Laursen)
- Class work: Innovation, delegation and incentives: Problems and opportunities

Basic agency theory and evidence

- P-A theory typically assumes:
  - "Principals" and "Agents"
  - The agent performs a work task for the principal
  - Principals and agents produce a joint surplus
  - Principals are risk neutral and agents are risk adverse
  - Principals and agents have a conflict of interest

Basic agency theory and evidence

- P-A theory typically assumes (con't):
  - Principals can only imperfectly observe the effort of agents (information asymmetry)
    - Impossible to observe the *input* to the work task
    - and it is impossible to measure work *output precisely*
  - Agents can be compensated through an hourly wage or through pay-for-performance
  - Since agents are risk adverse they demand a high premium for accepting risk in the standard P-A model

Basic agency theory and evidence

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The basic P-A model:

$x = e + \varepsilon$,

where x is output, e is effort by the employee, and ε is an error term. The error term has a variance, σ^2. σ^2 can said to represent uncertainty.

- e is unobservable for the principal and σ^2 is uncontrollable for the agent.
- The principals problem is to choose s so that the agent puts in effort, but is not overburdened with risk

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- The second-best contract, specifying how much to pay the agent, can take the following form :

  $s(x) = \alpha x + \beta$,

  where α is a measure of high-powered incentives ("the piece rate") and is β a transfer from the principal to the agent (that serves to satisfy the participation constraint)
- An analysis of the conditions that leads to maximization of the (certain) joint surplus gives rise to the following conclusions:
  - r varies inversely with α (r expresses the coefficient of risk aversion).
  - σ^2 varies inversely with α.
- This is the trade-off between risk-sharing and provision of incentives to supply effort.

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- Issues (Prendergast, 1999)
  - The problem with an hourly wage is that it does give agents incentives to do an effort
  - However, incentives may give rise to dysfunctional behavioural responses
    - People may do only what they are paid for;
    - even when it is not warranted
    - It may also crowd out "extrinsic motivation"
  - When agents have several tasks we call this "multitasking"

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- Issues (con't) (Prendergast, 1999)
- Subjective performance evaluation
  - Can often be necessary, but has problems because of:
    - "Brownnosing" of supervisors
    - Supervisors may give rewards that only deviate a little from a norm
    - Supervisors are reluctant to give bad marks to poorly performing employees
  - Team production concerns
    - Free riding problems emerge when compensation is given to a team
  - Relative performance evaluation
    - Is efficient, when the environment is versatile, so that agents are not penalized when common demand declines

Basic agency theory and evidence

- Empirical evidence
  - Agents do respond to incentives
  - Despite free riding problems, there appear to be significant productivity benefits from rewarding teams (due to peer pressure?)
  - Better wages attract better workers (pay-for-performance gives higher wages)
  - Although wages are higher, productivity gain can often (much) more than compensate for this, when pay-for-performance is applied

Basic agency theory and evidence

- Empirical evidence (con't)
  - Often, though, do incentives (both subjective and objective performance indicators) have unintended negative consequences
  - The jury is still out on the performance of relative performance evaluation
  - The evidence on the trade-off between risk and incentives is mixed (more about that later!)

The relationship between information technology, workplace organization and skilled labor

- The productivity benefits of information technology (IT) depends on investments in complementary changes in workplace organization.
- Complementarity between activities obtains if "… doing more of one thing increases the returns to doing (more of) the others" (Milgrom and Roberts, 1995: 181).

The relationship between information technology, workplace organization and skilled labor

- The evidence (Besnahan et al., 2002):
  - Supports the complementarity for productivity outcomes
  - And find that the complementarity positively increases the demand for skilled labor
  - In other words falling IT prices -> increased use of "new" work organization (team work), skilled labor and IT -> innovations -> higher productivity
  - However, innovation is measured as relative differences in the same industry in multifactor productivity – it is not measured directly.

New HRM Practices, complementarities, and the impact on innovation performance, CJE, 2003 (joint with Nicolai J Foss)

Keld Laursen
Department of Innovation and Organizational Economics,
Copenhagen Business School,
Kilevej 14a, 2000 Frederiksberg, Denmark
E-mail: kl.ino@cbs.dk,
http://www.druid.dk/laursen/

Organizational Complementarities: Motivation

- Recent research in contract economics (and in management research) has focussed the application of HRM (work) practices and on complementarities between them:
  - However the theoretical link between innovation performance and HRMP complementarities has not been clearly identified
  - The effect of HRMP complementarities on innovation performance has not been empirically tested

Measuring complementarities: Two methods

- Athey and Stern (NBER WP, 1998):
  - the “correlation approach”
  - the “production function approach”

Hypotheses (i)

- ***H1:*** The application of HRMP practices is conducive to innovation because:
  - The application of HRM practices may increase the level of decentralisation;
  - team practices, involving job-rotation are likely to provide coordination advantages in the sense that engineers (or “workers”) perform several tasks and therefore understand the technological problems of colleagues better;
  - teams often bring together knowledge and skills which — prior to then introduction of teams — existed separately, potentially resulting in incremental process and product improvements.

Hypotheses (ii)

- ***H2:*** However, the effect of such practices is stronger when the HRMPs are applied in 'systems', rather than alone.

The data

- Survey data from the DISKO project, 1996
- 684 manufacturing and 1,216 non-manufacturing firms (total of 1900 firms)
- The dependent variable, innovation:
  - if non-innovator then inno = 0
  - if the firm introduced new product/service new to:
    - the firm, then inno = 1
    - the country, then inno = 2
    - the world, then inno = 3

The independent variables

- The empirical model:

$$A_i = \alpha SIZE_i + \chi SECT_i + \delta LINK_i + \phi EXREL_i + \varphi SUBSID_i + \eta_j HRMP_i^j + .. + \eta_n HRMP_i^n + \varepsilon_i,$$

- However, HRMPs should be looked at from a systemic point of view ⇨ principal components analysis is one way of doing that

Factor loadings from PCA

Variable	*Factor 1*	*Factor 2*
HRMP1: Interdisciplinary workgroups	0.71	0.14
HRMP2: Quality circles	0.66	0.15
HRMP3: Systems for collection of employee proposals	0.65	0.04
HRMP4: Planned job rotation	0.62	0.08
HRMP5: Delegation of responsibility	0.57	0.03
HRMP6: Integration of functions	0.65	-0.05
HRMP7: Performance related pay	0.55	0.05
HRMP8: Firm-internal training	0.14	0.90
HRMP9: Firm-external training	0.02	0.92
Cumulative %	0.33	0.50

Regression table in portrait

Correlations amongst HRM systems and the firm's sectoral affiliation

	Factor 1	*p*-value	Factor 2	*p*-value
Scale intensive	0.16	0.000	0.05	0.031
Supplier dominated	0.08	0.001	-0.09	0.000
Science based	0.12	0.000	0.02	0.490
Specialised suppliers	0.15	0.000	-0.07	0.002
Crafts	-0.20	0.000	-0.11	0.000
Wholesale trade	0.00	0.936	0.08	0.001
Specialised services	-0.17	0.000	0.06	0.006
Scale intensive services	-0.05	0.041	-0.09	0.000
ICT intensive services	0.03	0.178	0.12	0.000

The Role of Organization for Technological Innovation

- 'Technological opportunity' (or sectoral affiliation) matters for innovation;
- strong external linkages (vertical and to knowledge institutions) matter as well;
- HRMPs matter, but much stronger when applied in systems, rather than alone;
- 'successful' HRMP systems are not equally important across sectors.

Uncertainty and Organizational forms

- OK, so the chosen organizational set-up matters for the ability to innovate;
- ...but does the external environment ("uncertainty") matter for the chosen organizational set-up?

Performance Pay, Delegation, and Multitasking under Uncertainty and Innovativeness: An Empirical Investigation, JEBO, 2005 (joint with Nicolai J Foss)

Keld Laursen
Department of Innovation and Organizational Economics,
Copenhagen Business School,
Kilevej 14a, 2000 Frederiksberg, Denmark
E-mail: kl.ino@cbs.dk,
http://www.druid.dk/laursen/

Background

- Problems with standard agency theory:
  - incentive pay and uncertainty (observed by Prendergast, 2002, JPE)
  - restrictions on workers' activities (the Holmström-Milgrom hypothesis).

Theory (i)

- In standard PA-theory, the agent receives a larger share of the joint surplus, the lower his/her aversion is to risk (in other words, α, the "piece rate," and r, the coefficient of risk aversion varies inversely)
- Environmental uncertainty has the effect of adding observation error to performance measures (i.e., increase measurement cost) This increases the risk that is imposed on agents.
- Accordingly, the testable prediction is that risk and performance pay correlate negatively

Theory (ii)

- However, as Prendergast (2002) documents, this prediction has not fared well in the face of the available empirical evidence.
- Specifically, Prendergast considers the available empirical evidence for the four classes of occupation of executives, sharecroppers, franchisees, and sales force workers:
  - In the case of ***executive compensation***, the evidence is "inconclusive".
  - For ***sharecroppers***, the fraction that they retain turns out to be increasing in the noisiness of financial returns that is directly counter to the agency prediction.
  - Evidence from studies of ***franchising*** suggest that the choice of whether to keep outlets in-house or franchise them is influenced by uncertainty in a direction opposite to the prediction of agency theory
  - The evidence on ***sales force*** integration is inconclusive.

Theory (iii)

- The standard model may be extended in various ways, notably by introducing monitoring considerations. In the "standard" setting, higher risk leads to more monitoring, because higher risk leads to a fall in high powered incentives (α), which in turn reduces effort, prompting an increase in monitoring
- Therefore, the costs of measuring the agent's performance in the various activities play a key role for how much the agent will be restricted.
- A key prediction from their multitask-agency model is that the more costly it is to measure the agent's performance in his/her main activities, the more his/her flexibility will be restricted.
- Since risk and measurement cost can reasonably be assumed to correlate directly, this reasoning would predict that as risk increases, the agent will tend to become increasingly constrained.

Theory (iv)

- In reality, much knowledge about how to optimally carry out the task resides with the agent, and may be too costly to transfer to corporate headquarters (or other managerial layers), because of problems of eliciting the correct information or because the relevant knowledge is of a highly "impacted," tacit or complex, kind.
- In this situation, delegation co-locates decision rights with this knowledge.
- Accordingly, the benefits from delegation are probably underestimated in the standard PA-model;
- and delegation generates incentive pay based on output.
- This is consistent with recent PA-model by Prendergast 2002, JPE

Theory (v)

- The Holmström and Milgrom hypothesis:
  - The more costly it is to measure the agent's performance in his/her main activities, the more his/her flexibility will be restricted
  - However, again, asymmetrical information about work tasks may obtain

Theory (vi)

The Prendergast P-A model:

- The agents are assumed to be risk-neutral.
  $x_i = e_i + \varepsilon_i$,
  where x_i is output, e_i is effort by the employee, and ε_i is an error term. The error term has a variance, σ^2. σ^2 can said to represent uncertainty.
- e_i is unobservable for the principal and ε_i (for all i) is known for the agent, but not for the principal (who only knows the underlying distribution).
- The agent can chose the activity j to work on so that
  $x_i - C(e_i) + B_i$
  is maximized. $C(e_i)$ is the cost of supplying effort and B_i is personal benefit.
- Higher uncertainty (σ^2) -> more delegation -> delegation (choice of activity — for instance, the engineer chosen which solution to work on) generates incentive pay based on output.

Hypotheses (i)

- **Hypothesis 1**: *There is an overall positive and significant relation between environmental uncertainty and the use of performance pay.*

Hypotheses (ii)

- **Hypothesis 2a**: *Delegation and environmental uncertainty are positively correlated.*
- **Hypothesis 2b**: After controlling for delegation, there will be no relationship between uncertainty and performance pay

Hypotheses (iii)

- **Hypothesis 3**: *The strength of the correlation between environmental uncertainty and the use of performance pay is sector dependent, so that the correlation within more "dynamic" sectors is stronger than in less "dynamic" sectors*

Hypotheses (iv)

- **Hypothesis 4**: *Firms that are placed in environments characterized by high uncertainty will restrict the activities that their employees can engage in less than those that are placed in low uncertainty environments.*

How to measure uncertainty?

- The previous literature has used e.g.:
  - The average proportion of discontinued outlets in the franchising sector
  - The number of calls it takes to close a sale, averaged across the salespeople at the responding firm
  - For the analysis of sharecroppers, the coefficient of variation of yield has been used
  - Variation over time of aggregate sales data
  - Survey-based data, assessing the stability in sales and forecasting accuracy
  - For executive pay, variation in returns

How to measure uncertainty?

- We consider three measures of uncertainty:
  - The extent to which firms are innovative
  - The perceived increase in the level of competition
  - Previous within-industry variance in profitability.

The empirical model

- The set-up:

$$\text{Prob}(O_i = 0..j) = \chi SECT_i + \alpha LOGSIZE_i + \varphi SUBSID_i + \eta INNO + \psi COMP_i + \omega PROFITVAR + \varepsilon_i,$$

where Prob(O_i = 0..j) expresses the firms' probability of adopting a given organizational practice (such as pay-for-performance or delegation of responsibility) to a certain degree within the firm ("0" = no use, "1" = less than 25% of the workforce involved, "2" = 25-50% of the workforce, and "3" = more than 50% of the workforce involved).

- SECT = Sectoral affiliation
- SIZE = Number of employees
- SUBSID = Subsidiary of a larger firm
- INNO =Innovation (level of novelty)
- COMP = Increase in the level of competition
- PROFITVAR = Within-firm/industry variance in profitability

The Data

- Survey data from the DISKO project, 1996
- 684 manufacturing and 1,216 non-manufacturing firms (total of 1900 firms)
- We select a sub-sample of firms with more than 30 employees (993 firms in total).

Descriptive statistics for a set of DISKO variables (N = 993)

		Number of firms	% of sample
Industry affiliation	Low-KI	390	39.3
	Medium-KI	366	36.9
	High-KI	237	23.9
Number of employees	31-100 employees	312	31.4
(SIZE*)	101-200 employees	203	20.4
	200+ employees	478	48.1
Subsidiary	No	409	41.2
(SUBSID)	Yes	584	58.8
Competition	Strongly decreased	1	0.1
(COMP)	Somewhat decreased	10	1.0
	Unchanged	194	19.5
	Somewhat increased	339	34.1
	Strongly increased	449	45.2
Product innovation	No innovation	391	39.4
(INNOF)	Innovation new to the firm	434	43.7
(INNOC)	Innovation new to the country	89	9.0
(INNOW)	Innovation new to the world	79	8.0
Pay-for-performance	Not used	525	52.9
(PPAY)	< 25% of the workforce	194	19.5
	25-50% of the workforce	79	8.0
	> 50% of the workforce	195	19.6
Delegation	Not used	103	10.4
(DR)	< 25% of the workforce	240	24.2
	25-50% of the workforce	265	26.7
	> 50% of the workforce	385	38.8
Quality circles	Not used	522	52.6
(QC)	< 25% of the workforce	264	26.6
	25-50% of the workforce	111	11.2
	> 50% of the workforce	96	9.7
Planned job rotation	Not used	550	55.4
(PJR)	< 25% of the workforce	288	29.0
	25-50% of the workforce	93	9.4
	> 50% of the workforce	62	6.2

Econometric issues

- The dependent variables are discrete and inherently ordered multinomial-choice variables; accordingly the ordered probit model is applied as the main means of estimation
- However, we have argued that uncertainty gives rise to adoption of delegation of responsibility which in turn gives rise to pay-for-performance, therefore we may have an endogeniety-problem
- Nevertheless, if we assume independence between the error terms in these two equations, and further assume that errors are normally distributed, then the equations can be estimated one by one (but these assumptions may be wrong).
- Possible solution: Joint estimation using a bivariate probit model (although there is a serious limitation with bivariate probit models in this context)

Ordered probit estimation explaining the adoption of delegation and pay-for-performance (N = 993) Marginaleffects.ppt

Dependent variable / Independent variables	Model (i) PPAY (Pay-for-performance)		Model (ii) DR (Delegation of responsibility)		Model (iii) PPAY (Pay-for-performance)		Model (iv) PPAY x DR Pay-for-perform. times delegation	
	Estimate	*p*-value	Estimate	*p*-value	Estimate	*p*-value	Estimate	*p*-value
CONSTANT	-0.980	0.000	0.225	0.308	-1.205	0.000	-1.127	0.000
LOW_KI			Benchmark					
MEDIUM_KI	0.048	0.581	0.172	0.038	0.020	0.815	0.020	0.824
HIGH_KI	-0.046	0.640	0.236	0.013	-0.087	0.383	-0.018	0.855
LOGSIZE	0.125	0.002	0.105	0.009	0.109	0.008	0.128	0.002
SUBSID	0.152	0.054	0.077	0.317	0.142	0.074	0.182	0.023
INNOF	0.212	0.013	0.219	0.006	0.178	0.037	0.264	0.002
INNOC	0.262	0.062	-0.016	0.911	0.263	0.065	0.318	0.024
INNOW	0.477	0.002	0.217	0.117	0.446	0.003	0.503	0.001
COMP	-0.017	0.728	0.075	0.092	-0.026	0.601	-0.010	0.837
PROFITVAR	3.049	0.000	1.477	0.293	2.841	0.000	2.879	0.000
DELEGATION (DR)					0.194	0.000		
Log likelihood	-1144.73		-1265.37		-1131.67		-1396.27	
Restricted log likelihood	-1168.76		-1289.07		-1168.76		-1424.42	
Likelihood ratio test	0.000		0.000		0.000		0.000	

FIML estimates of a bivariate probit model explaining the adoption of delegation and pay-for-performance (N = 993)

Dependent variable / Independent variables	Model (i) DR (Delegation of responsibility)		Model (ii) PPAY (Pay-for-performance)	
	Estimate	*p*-value	Estimate	*p*-value
CONSTANT	-0.160	0.636	-2.079	0.000
LOW_KI	Benchmark		Benchmark	
MEDIUM_KI	0.115	0.387	-0.018	0.850
HIGH_KI	0.115	0.455	-0.168	0.117
LOGSIZE	0.151	0.024	0.080	0.097
SUBSID	0.167	0.184	0.148	0.113
INNOF	0.348	0.007	0.134	0.192
INNOC	0.047	0.820	0.284	0.062
INNOW	0.159	0.492	0.491	0.005
COMP	0.076	0.261	-0.034	0.530
PROFITVAR	4.931	0.051	1.483	0.149
DELEGATION (DR)			1.689	0.000
Log likelihood	-965.140			
Likelihood ratio test	0.000			

Probit estimation explaining the adoption of pay-for-performance, sectoral estimation (N = 993)

		Estimate	*p*-value
CONSTANT	Low-KI	-0.764	0.047
	Medium-KI	-0.602	0.109
	High-KI	-1.961	0.000
LOGSIZE	Low-KI	0.045	0.524
	Medium-KI	0.128	0.033
	High-KI	0.184	0.061
SUBSID	Low-KI	0.275	0.034
	Medium-KI	0.021	0.872
	High-KI	0.201	0.228
INNOF	Low-KI	0.240	0.078
	Medium-KI	0.320	0.020
	High-KI	0.020	0.918
INNOC	Low-KI	0.336	0.208
	Medium-KI	0.033	0.892
	High-KI	0.460	0.055
INNOW	Low-KI	0.240	0.411
	Medium-KI	0.478	0.033
	High-KI	0.685	0.027
COMP	Low-KI	0.029	0.693
	Medium-KI	-0.150	0.069
	High-KI	0.104	0.317
PROFITVAR	Low-KI	1.099	0.385
	Medium-KI	6.739	0.019
	High-KI	8.861	0.012
Log likelihood		-1134.3	
Restricted log likelihood		-1168.8	
Likelihood ratio test		0.000	

Ordered probit estimation explaining the adoption of quality circles and planned job rotation (N = 993)

Dependent variable / Independent variables	Model (i) QC (Quality circles)		Model (ii) PJR (Planned job rotation)	
	Estimate	*p*-value	Estimate	*p*-value
CONSTANT	-1.133	0.000	-1.456	0.000
LOW_KI			Benchmark	
MEDIUM_KI	0.006	0.943	0.119	0.168
HIGH_KI	0.226	0.021	0.021	0.832
LOGSIZE	0.140	0.001	0.166	0.000
SUBSID	0.203	0.014	0.066	0.414
INNOF	0.293	0.001	0.248	0.004
INNOC	0.250	0.057	0.286	0.035
INNOW	0.184	0.202	0.412	0.004
COMP	0.005	0.908	0.070	0.136
PROFITVAR	1.152	0.314	1.108	0.362
Log likelihood	-1122.42		-1045.62	
Restricted log likelihood	-1152.94		-1073.64	
Likelihood ratio test	0.000		0.000	

Conclusions

- There was an overall positive and significant relation between environmental uncertainty and the use of performance pay in the sense that the likelihood of adopting pay-for-performance increases with firms' ability to produce product innovations, in particular when the majority of the workforce is involved in the pay-for-performance schemes;
- ...and this relationship was found to be the strongest for firms affiliated to high knowledge-intensity sectors.

Conclusions

- Concerning the claim that delegation and environmental uncertainty are positively correlated, we found support for this to the extent that if firms face more uncertain environments, then they are more likely to use delegation of responsibility, conditional on the observation that delegation involves the majority of the workforce.
- Although the parameter for the measure of within-firm/industry variance in profitability turned out not to be significant (albeit positive) in explaining the use of delegation in firms, when using the ordered probit model, the opposite prediction from standard agency theory (a negative relation) found no support in the available evidence.

Conclusions

- Firms which are placed in environments characterized by high uncertainty restrict the activities that their employees can engage in *less* than those that are placed in low uncertainty environments… (as opposed to the Holmström-Milgrom hypothesis)
- ….we conjecture that "dynamic" firms often stimulate multitasking for reasons of knowledge-integration and sharing.

Keld Laursen
DRUID, Department of Innovation and Organizational Economics,
Copenhagen Business School
http://www.druid.dk/laursen/
E-mail: kl.ino@cbs.dk

Class work

- using the HBR case on “Innostat”
  - Read the article
  - Answer the related questions in small groups
  - We discuss the possible answers on class