Incentive System for Inventors

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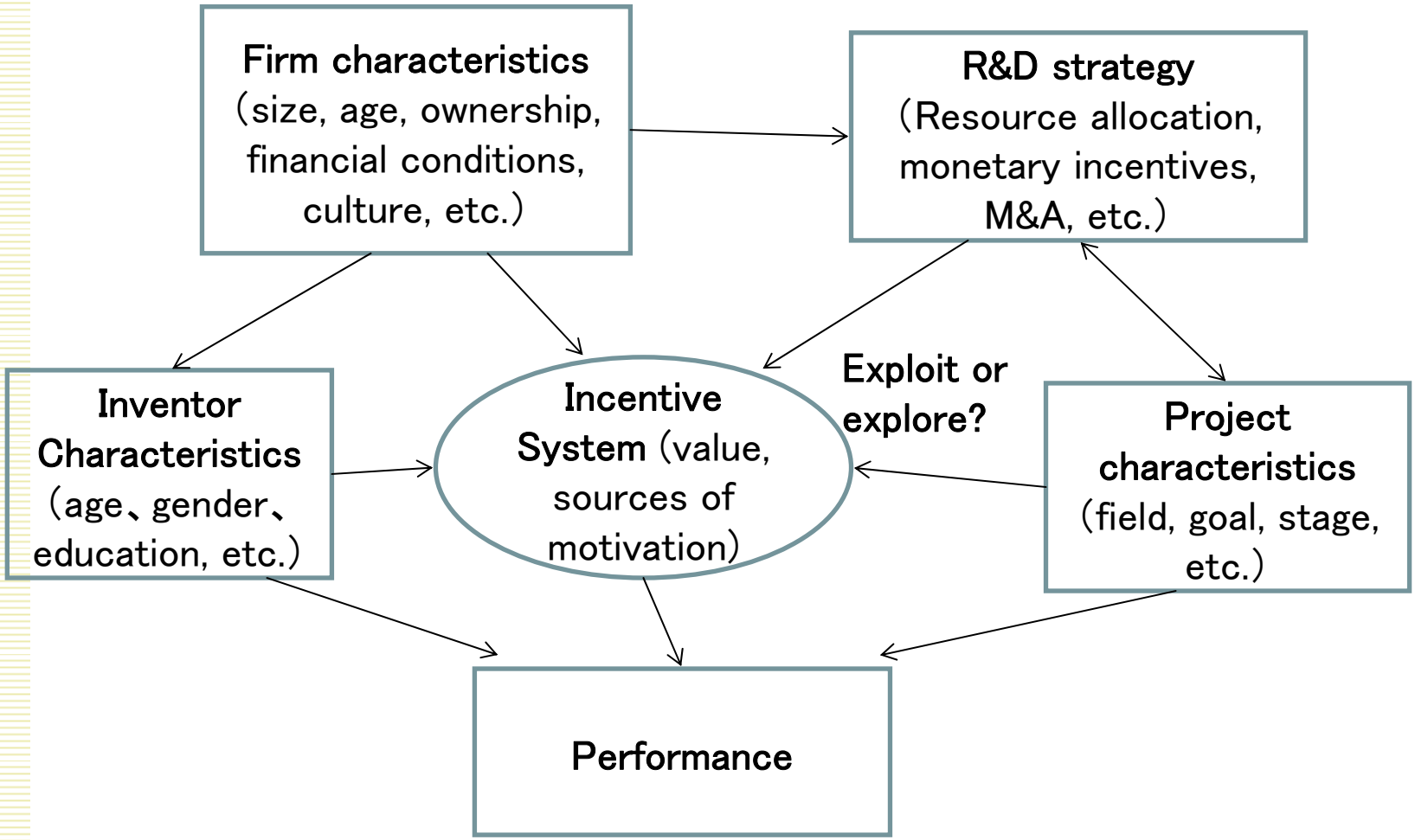
Motivation

- **Understanding what motivate inventors is important.**
  - Economists predict that production of knowledge is underprovided in the presence of spillovers. This problem might be alleviated if there is an additional mechanism to motivate R&D efforts.
  - Scientific and technical knowledge is the source of economic growth.
- **The optimal incentive system for inventors may vary across different R&D goals and stages and across different inventor characteristics.**
  - Firms needs to integrate and build upon its current competencies (exploitation) while simultaneously developing fundamentally new capabilities (exploration) . (March 1991, Teece, Pisano, & Shuen 1997, Tushman & O'Reilly 1997, Roberts 2004).
- **Is monetary compensation a mere response to the legal requirement by the patent law to pay "appropriate compensation" to inventors?**
- Project-level data from the inventor survey allows us to investigate how inventors are motivated.

Factors affecting inventor motivation

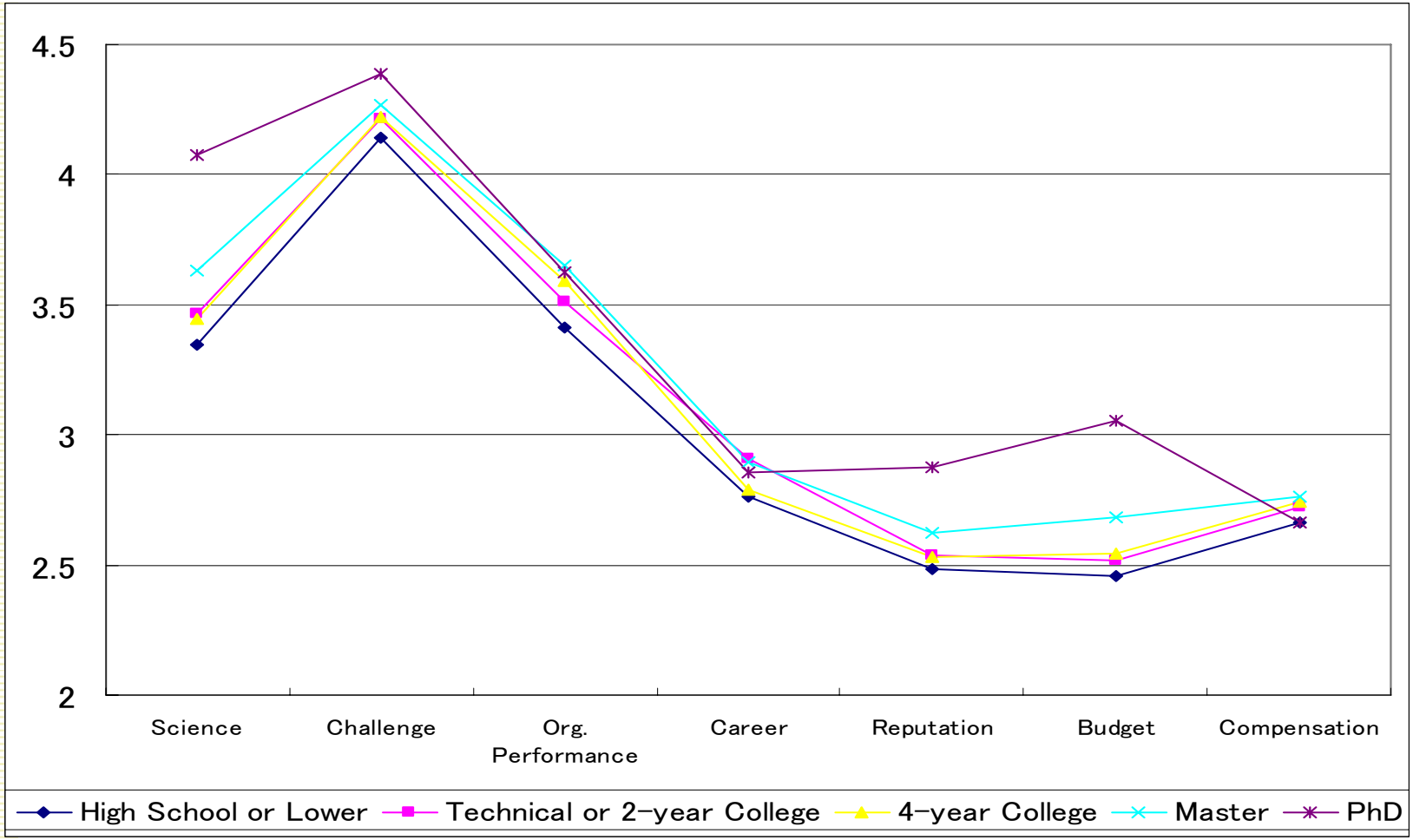


Seven motivation drivers analyzed

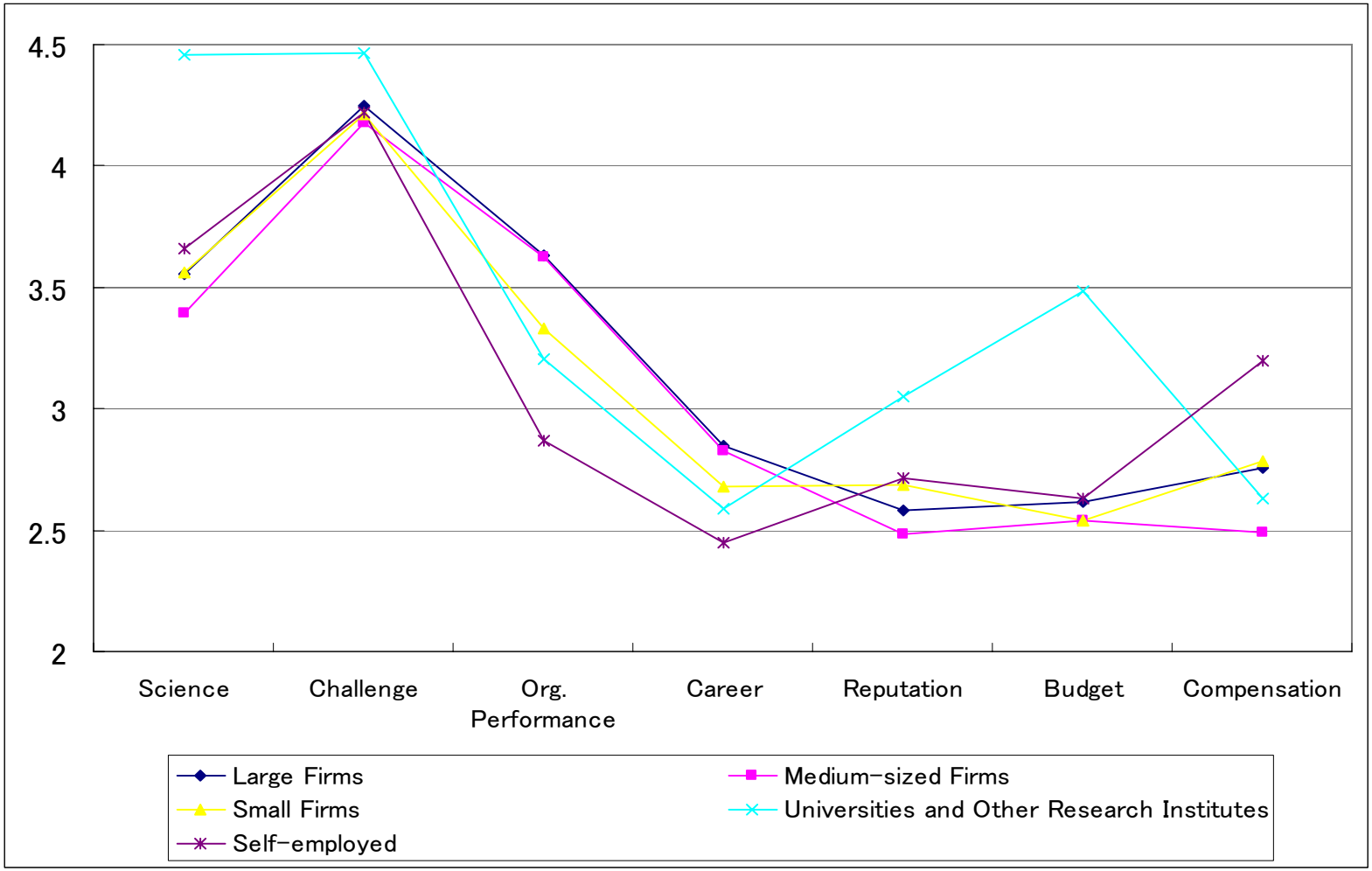
Survey question: How important was each of the following factors as a source of motivation for your invention? (Measured by 5 point Likert scale: 1=absolutely unimportant – 5=very important)

- **SCIENCE**: Satisfaction from contributing to the progress of science and technology.
- **CHALLENG**: Satisfaction from solving challenging technical problems.
- **ORG_PERFORMANCE**: Performance enhancement of your organization
- **CAREER**: Career advances.
- **REPUTATION**: Reputation and prestige of you and your organization.
- **BUDGET**: Improved research conditions such as more budget.
- **MONEY**: Monetary rewards.

Average responses by educational level



Average responses by organizational type



Relationship with inventor productivity

- How are seven motivation drivers associated with inventor productivity?
  - We use both quantitative and qualitative productivity measures:

    Size_pat : the size of domestic patent grants the research is expected to generate (6 point scale)

    Dom_pat_value: the inventor' s ranking of the economic value of the surveyed patent among other comparable patents in the same technological field concurrently granted in Japan (4 point scale)

- We find that SCIENCE and CHALLENGE are closely associated with both measures of inventor productivity (See Table 1).
  - The results should not be interpreted as the effect of the motivation drivers because the causality may be opposite (e.g. project with high expected value may attract those with "strong tastes for science or challenge").

- There is a slight difference between the quantity and quality measures.
  - Inventors whose resources are not secured are likely to produce more patents.
  - Inventors who rate reputation as important are likely to produce more valuable patents.

Table 1: Relationship with patent value

Ordered logit model estimation

Dependent Variable	Size_pat (# of patents expected)		Dom_pat_value (Relative economic value)	
	Coefficient	z-statistics	Coefficient	z-statistics
Science	0.1855***	5.65	0.2789***	7.15
Challenge	0.1083**	2.54	0.2684***	4.89
Org. Performance	0.0460	1.38	0.0022	0.05
Career	0.0093	0.26	0.0322	0.71
Reputation	−0.0049	−0.13	0.1201***	2.67
Budget	0.1115***	3.14	0.0199	0.48
Money	0.0250	0.73	−0.0147	−0.36

We control for inventor characteristics (age, gender, tenure, academic degree), patent characteristics (number of inventors/applicants, patent category), organizational characteristics (size, functions), and project characteristics (goal, type, stage).

***, **, and * indicate significant level at 1%, 5%, and 10%, respectively.

Table 2: How are motivators formed?

- How are motivation drivers associated with individual, project, and firm characteristics? (Results from ordered logit model estimation)

	Science	Challenge	Org. Perf.	Career	Reputat' n	Budget	Money
# of inventors	0.006	−0.028	**0.076*** **	0.026	0.022	**0.068*** **	−0.021
Age	0.019*	**0.027*** **	−0.005	−0.004	0.006	**0.030*** **	−0.013
High school graduate	−0.011	−0.191	**−0.390** **	**0.386*** **	−0.036	0.107	−0.204
Ph.D	0.282*	−0.004	0.079	−0.005	0.218	0.072	−0.111
R&D division	**0.536*** **	**0.324** **	0.008	**0.244** **	**0.233** **	**0.529*** **	0.107
New business line	**0.392*** **	0.246*	−0.010	**0.316*** **	**0.229** **	**0.367*** **	0.130
Core business	**0.407*** **	**0.304*** **	0.174*	**0.215** **	**0.279*** **	−0.017	0.103
New technology base	**0.330** **	−0.039	**−0.439*** **	−0.047	−0.067	0.176	0.047
Basic research	**0.668*** **	**0.432*** **	0.043	0.050	−0.034	**0.307*** **	−0.045
Comm. of new seeds	**0.467*** **	0.044	−0.027	0.107	0.162*	0.172*	0.139
Explor. of tech seeds	**0.336** **	0.242*	−0.189	0.035	0.145	0.008	0.017
Firm size (=ln(sale))	**0.084*** **	0.029	0.024	**0.059** **	0.024	**0.067** **	**0.081*** **
Capital Intensity	−0.337	−0.251	**0.976** **	0.376	0.060	0.159	−0.681*

Other variables that do not have significant coefficients are omitted.
***, **, and * indicate significant level at 1%, 5%, and 10%, respectively.

Implications of Table 2

- Inventors in large projects care more about organizational performance and resources they receive.
- Older inventors, presumably having more decision authority, highly rate challenge and budget as more important than their younger ones.
- Inventors who work to develop a new business line or to support core businesses more highly rate science, challenge, career advancement, and reputation more important drivers than those working for non-core businesses.
- Science is a primary motivation driver for those working on exploratory themes (associated with new technology base, basic research, commercialization of new seeds, and exploration of technological seeds).
- Organizational performance matters more for inventors when firms have large tangible fixed assets – hence failure in R&D may result in large adjustment cost (Chan, Nickerson and Owan 2007).

"Taste" for Science

- "Taste" for Science (Stern 1999)
  - Researchers may have intrinsic preference for contributing to the accumulation of scientific knowledge and for receiving recognition from their peers for discoveries.
- Some firms prefer hiring researchers with taste for science and allow them to pursue individual research agenda.
- Why?
  - (Productivity) Early access to scientific discoveries raises R&D productivity.
  - (Screening) "Taste" for science is correlated with the researcher's ability.
  - Researchers with "taste" for science are willing to trade off wage premium with good research environment.

“Productivity” vs. “Screening” Explanations

- Correlation between science orientation and high R&D productivity confounds these two effects.
  - Rosenberg (1889), Cohen and Levinthal (1989, 1990), and Arora and Gambardella (1994)

- If the “productivity” explanation is true, cooperation with scientific community, reading scientific and technical literature, and publishing in academic journals should help to raise inventor productivity.

- The analysis indicates that the “productivity” effect may explain only a portion of overall impact of “taste for science” on productivity, and especially is limited for the qualitative measure. (see Table 3)
  - Patent value is lower for those with co-inventors from universities, etc.
  - All variables related to activities to learn scientific discoveries except for “publish in academic journals” become insignificant in explaining patent value.
  - The coefficient for Science does not decline much as we add the above variables in estimation.
  - The “screening” explanation may be more important.

Table 3 Ordered Probit Estimates of Inventor Productivity

Dependent Variable	Size_pat		Dom_pat_value	
Number of inventors	0.0737***	0.0639***	0.0910***	0.0745***
	(0.0156)	(0.0157)	(0.0187)	(0.0192)
Age	0.0217***	0.0220***	0.0166***	0.0152**
	(0.0056)	(0.0058)	(0.0063)	(0.0066)
PhD	0.2962***	0.1325	0.4319***	0.2348*
	(0.1075)	(0.1100)	(0.1257)	(0.1283)
Working in a big firm	0.5121***	0.4858***	-0.1765***	-0.1880*
	(0.0861)	(0.0884)	(0.1044)	(0.1083)
Belong to R&D division	0.4311***	0.3833***	0.0036	0.0316
	(0.1051)	(0.1063)	(0.1231)	(0.1260)
New business line	0.5890***	0.5454***	0.2039*	0.2206**
	(0.0874)	(0.0889)	(0.1050)	(0.1059)
Basic research	0.2537***	0.1762**	0.2064**	0.1395
	(0.0774)	(0.0800)	(0.0921)	(0.0930)
Applied research	0.2701***	0.2238***	0.2136***	0.1881***
	(0.0610)	(0.0620)	(0.0697)	(0.0707)
Motivation: Science	**0.2548*** **	**0.1931*** **	**0.3938*** **	**0.3696*** **
	(0.0298)	**(0.0310)**	**(0.0343)**	**(0.0365)**
Co-inventors from universities, etc.		-0.5176***		0.1453
		(0.1936)		(0.2522)
Cooperation with universities, etc.		0.4519***		0.0892
		(0.1281)		(0.1500)
Importance of science literature in getting idea		0.1084***		-0.0020
		(0.0193)		(0.0231)
Published the discovery in journals		0.4077***		0.7693***
		(0.0842)		(0.0978)
Pseudo R-squared	0.0546	0.0616	0.0475	0.0571
# of Observations	4522	4453	3306	3244

Other independent variables include number of applicants, gender, tenure, and other educational background of surveyed inventor, types of employers, and other project characteristics. Robust standard errors are in the parentheses. *, ** and *** indicate significance levels of 10%, 5%, and 1% respectively.

Other findings on "Taste for science"

- "Taste for science" is presumably correlated with inventor ability and firms also allocate resources to raise their reputation to attract more talented researchers.
  - **Ptn_goal_rep** (importance of the company reputation in registering the patent) and **Science** ("taste for science") are highly correlated.

- "Taste for science" is more closely associated with inventor productivity in "exploration" (commercialization of potentially useful scientific or technological discoveries, or exploration of new technical seeds) than in "exploitation" (solving important technological issues of the business of the firm)

Aren't monetary rewards working?

- Monetary rewards do not seem to have a great impact on inventor productivity as a motivator nor are much correlated with project or firm characteristics (See Table 1&2).
  - Then, the purposes of monetary rewards for invention are limited to (1) conforming to the patent law (i.e. pay "appropriate compensation" to inventors); and (2) attracting talented researchers.
- Be careful! – monetary rewards only work when the firm offers them. But, the inventor survey did not ask which firms offered them.
  - Low value of MONEY may result from either no provision of monetary rewards or lack of response to existing ones.
- We construct the dummy variable INCENTV: =1 if inventor thinks monetary rewards were an important motivator (i.e. MONEY = 4 or 5).
  - Theoretically, INCTV =1 only when the firm offers some form of monetary rewards AND they succeed to motivate the inventor.

Self-selection problem

- Another serious problem is that a firm's decision to adopt incentives for inventors is likely to be influenced by unobserved factors that affect the value of invention.
  - e.g. competitive market situation, state of product pipeline, quality of researchers, etc.
- To overcome this difficulty, we estimate the inventor productivity measures and INCENTV simultaneously.

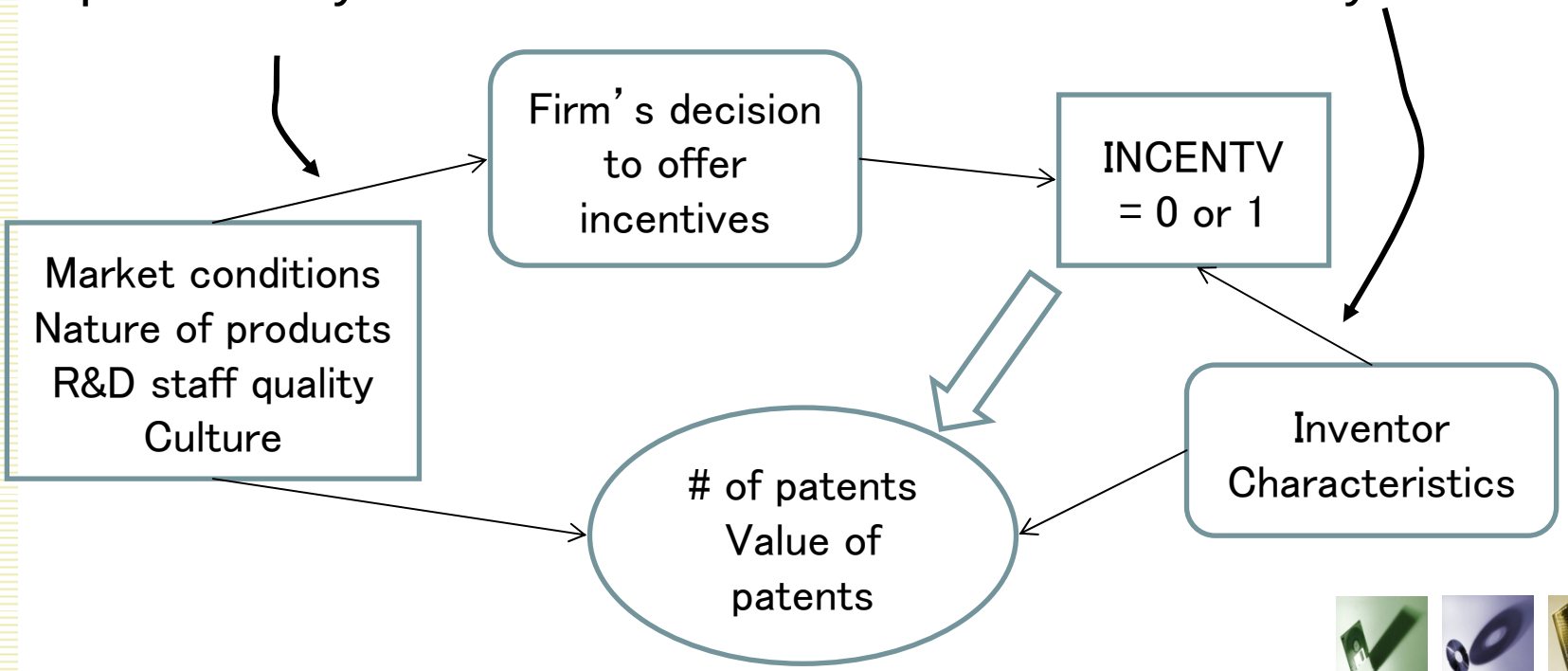


Table 4: Treatment effect model estimation (A)

Dependent Variable	(1) Size_pat		(2) Dom_pat_value	
Maximum Likelihood Estimation	Coefficient	S.E.	Coefficient	S.E.
# of investors	0.0279***	0.0107	0.0442***	0.0105
Master degree	0.0935**	0.0435	0.0545	0.0439
Ph.D	0.1548**	0.0719	0.1719**	0.0710
ln(sale)	0.0587***	0.0126	-0.0331**	0.0130
Working in R&D division	0.2132***	0.0547	-0.0389	0.0582
New business line	0.3145***	0.0555	0.0726	0.0572
Reinforcing core business	0.0721	0.0478	0.0765	0.0496
Basic research	0.1016**	0.0498	0.1045**	0.0498
Applied research	0.1362***	0.0384	0.1307***	0.0383
Invention type: product	-0.0526	0.0466	-0.1518***	0.0464
Invention type: process	-0.165***	0.0494	-0.1473***	0.0505
Science	**0.1931*** **	**0.0203**	**0.2446*** **	**0.0210**
Incentv	**1.4617*** **	**0.0920**	**1.2798*** **	**0.1131**
# of observations	3219		2365	
Prob > χ_2	0.0000		0.0000	

Other independent variables include number of applicants, age, gender, tenure, and other academic background, and other project characteristics.
*, ** and *** indicate significance levels of 10%, 5%, and 1% respectively.

Table 5: Treatment effect model estimation (B)

Dependent Variable: INCTV	(1)		(2)	
	Coefficient	S.D.	Coefficient	S.D.
Foreign ownership (%)	0.0004	0.0015	0.0005	0.0018
Firm age	0.0045*	0.0027	0.0043	0.0034
ln(sale)	**0.0457*** **	**0.0151**	**0.0622*** **	**0.0179**
Science (normalized)	**-0.2601*** **	**0.0272**	**-0.2922*** **	**0.0323**
Instruments				
Advertising expense /sale	-0.5468	1.7765	2.5025	2.0840
Female employee ratio (%)	**0.6793*** **	**0.2182**	**0.5360** **	**0.2727**
# of observations	3309		2433	

*, ** and *** indicate significance levels of 10%, 5%, and 1% respectively.

Other findings on monetary rewards

- The effects of monetary rewards for inventors are not significantly different between “exploration” and “exploitation”.
- A successful introduction of monetary rewards is less likely when inventors have strong “taste for science”.
  - Either the firm decides not to introduce such incentives or inventors do not respond to monetary rewards.
- The effect of “taste for science” on patent value is smaller in the presence of monetary rewards. A similar result cannot be obtained for the effect on the number of patents generated.
  - Inventors who otherwise pursue risky projects aimed at technological leap might shift to safer and predictable themes in the presence of monetary incentives.

Conclusion

- Under-provision of R&D efforts may not be an issue at the inventor-level because “taste for science” and “taste for challenge” are major motivation drivers for inventors.
- Firms may benefit from hiring those with strong taste for science because (1) they are more motivated, (2) they will increase the absorptive capacity of firms, and (3) taste for science is correlated with ability.
- Unlike the conventional wisdom, there is some evidence that monetary rewards may be an effective motivation driver where they are introduced.