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Modeling and Analyzing Academic Researcher Behavior

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Abstract. *This paper suggests a theoretical framework for analyzing the mechanism of the behavior of academic researchers whose interests are tangled and vary widely in academic factors (the intrinsic satisfaction in conducting research, the improvement in individual research ability, etc.) or non-academic factors (career rewards, financial rewards, etc.). Furthermore, each researcher also has his/her different academic stances in their preferences about academic freedom and academic entrepreneurship. Understanding the behavior of academic researchers will contribute to nurture young researchers, to improve the standard of research and education as well as to boost collaboration in academia-industry. In particular, as open innovation is increasingly in need of the involvement of university researchers, to establish a successful approach to entice researchers into enterprises' research, companies must comprehend the behavior of university researchers who have multiple complex motivations. The paper explores academic researchers' behaviors through optimizing their utility functions, i.e. the satisfaction obtained by their research outputs. This paper characterizes these outputs as the results of researchers' 3C: Competence (the ability to implement the research), Commitment (the effort to do the research), and Contribution (finding meaning in the research). Most of the previous research utilized the empirical methods to study researcher's motivation. Without adopting economic theory into the analysis, the past literature could not offer a deeper understanding of researcher's behavior. Our contribution is important both conceptually and practically because it provides the first theoretical framework to study the mechanism of researcher's behavior.*

Keywords: *Academia-Industry, researcher behavior, ulrich model's 3C.*

1. Introduction

In recent years, universities have dramatically accelerated its involvement in business and entrepreneurial activities. As a result, the assignment of university has dramatically changed: it has become more and more entrepreneurial (Siegel et al., 2007). Universities not only have to provide education and research, but they also have to be involved in the commercialization of their scientific results. University researchers, besides teaching and research, have come under increasing pressure to participate in the commercialization of academic research. This is the problem of balancing the *academic freedom*[1] and *academic entrepreneurship*.

In contrast to researchers in the private sector, motivation of academic researchers partly stems from the concept academic freedom. Accordingly, the intrinsic motivation of academics, unlike researchers in industry, is to value independence in choosing their research agenda rather than monetary rewards. What happens if researcher job becomes more involved with the monetary factors? In some cases, the decision to collaborate with industry is influenced by perceived threats to a researchers academic freedom (Tartari & Breschi, 2012).

Although the main concern of academics is that industry involvement might restrict academic freedom, academics still express significant support for the collaboration with industry particularly when it is related to their

[1] *Academic freedom* has two main components: freedom to conduct research (*academic choice*: the ability to choose one's own research topics or choose their own research agendas), and freedom to communicate research (whether the scientist feels constraints in disclosing, communicating and sharing this research with others, i.e. the *norms of open science*) (Behrens and Gray, 2001).

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research (Lee, 1996). Moreover, empirical findings in Looy et al. (2004, 2006); Wash (2009) suggest that the engagement in entrepreneurial activities coincides with increased outputs of research; activities in both do not hamper each other. Why does the academia-industry collaboration have such controversial effects on the behavior of academic researchers? Literature indicated that there are some certain types of researchers suitable for the collaboration.

D'Este and Perkmann (2010) found that although researchers in the UK engage with industry to further their research rather than to commercialize their knowledge, they have different motivations to collaborate depending on the channels of engagement. Lam (2010, 2011) found the similar results. Davis et al. (2009) also found that scientists oriented towards basic research, and scientists who had previously worked in industry, were concerned that university patenting would negatively affect both aspects of academic freedom. Highly productive researchers, by contrast, were less apprehensive about either effect. The less productive basic researchers are especially worried about the effects on academics ability to choose their own research agendas. Scientists who had received research council grants, and full professors, are skeptical as regard to the effects on academic choice.

This exploration of researchers' motivation has attracted a growing interest in literature. Most of these studies have been conducted through data surveys among universities and their researching staff, or direct interviews with academic researchers. Then, conclusions and insights concerning researcher's individual motivation were drawn by analyzing the collected facts. In short, the current analytical method is an empirical method. However, despite having numerous studies, still less is known about the interaction as well as the mechanism between the various internal factors of the researchers (the intrinsic satisfaction, the improvement in research ability, the research effort, finding meaning in the research, career rewards, financial rewards, etc.) and their academic stances (preferences about academic freedom and academic entrepreneurship). The current analytical method has been challenged, and it needs to be complemented by a plausible theory. As far as we are aware of, this paper is the first to offer a theoretical framework to explore academic researchers' motivation within the context of university-industry relationships and academic freedom.

2. Theoretical Model (Economics and Researcher Behavior)

To build a model of researcher behavior, the authors have evaluated several approaches. Among them, there are two popular thinkings in economics, that is, if considering the researcher as a knowledge producer, we will adopt a kind of production function of research into the model. This scheme will characterize the researcher as the one in industry. Alternatively, assuming that the researcher is a consumer who is enjoying his scientific outputs, we will construct utility function for the researcher. However, as shown by the following Table 1, due to the fundamental differences between university and industry researchers in the motivation of conducting scientific research, we adopted the utility approach in our paper. The intrinsic motivation of academics, unlike researchers in industry, is to value independence in choosing their research agenda more highly than monetary rewards.

Table 1.
Academic entrepreneurial differences (Jain et al., 2009)

	Academic/Entrepreneurial
Norms	Universalism / Uniqueness
	Communism / Private property
	Disinterestedness / Passion
	Skepticism / Optimism
Processes	Experimentation / Focus
	Long-term/Short-term Orientation
	Individualistic-Small group/Team management
Outputs	Papers / Products
	Peer recognition (or status) / Profits

2.1. Ulrich 3Cs

Ulrich (2009) developed a concept called 3C (Competence, Commitment, Contribution) to manage and evaluate the performance of human resource. Competence is "the ability to do the work". Competence means that individuals have the knowledge, skills and values required for today's and tomorrow's jobs. Commitment is "the effort to do the work". Committed researchers work hard; put in their time. Contribution is "finding meaning (or intrinsic motivation[2]) in their work".

According to this 3C thinking, to give the best performance of a work, the man 1) not only has to possess an ability to do it such as skills or knowledge, 2) but also gives his best effort for the work (for example, working time), and 3) he must have an intrinsic motivation to do the work or finding meaning in the work he does. If any one of these three Cs is missing, the other two will not replace it. Highly competent researchers who are not committed or are not contributing in conducting research will give low performance on research outputs.

Dave Ulrich Model 3C
= Competence x Commitment x Contribution

2.2. Formation of Utility Function

1. Each academic researcher owns three resources:
Competence (C_1), commitment (C_2), and contribution (C_3) defined as Ulrich's 3C - that are able to generate two types of knowledge-based outputs: academic output (X) and commercial research output (Y). The concepts *academic* or *commercial* are just relatively characterized by their potentiality of commercialization. They will be affected by various external factors surrounding the researcher. They will be determined according to the particular state of the researcher. Broadly speaking, one academic output resulted from a basic research originated by a researcher may be a commercial research output for others.

In the regards to the number of outputs that the researcher is able to generate, each of the two knowledge-based outputs and should be also considered as one representative output for all producible academic and commercial outputs respectively.
The assumed relations between C_1, C_2, C_3, and X, Y are described as follows:

- *Competence* (C_1): the ability to do the work.

We assume that the competence C_1 of a researcher comprises academic competence C_{1X} and profit-making competence C_{1Y}. Academic competence C_{1X} is a kind of competence concerning the basic research ability. It is assumed to be indispensable for generating academic output X. Similarly, profit-making competence C_{1Y} is indispensable for producing commercial output Y. Practically, it is difficult to make a clear distinction between C_{1X} and C_{1Y}.
Since the competence C_{1Y} is generally cumulated through the development of C_{1X}, we also assume that the competence $C_{1Y} = g\,(C_{1X(0)})$ with g as a concave function and $C_{1X(0)}$ is the antecedent academic competence.

- *Commitment* (C_2): the effort to do the work.

Here, there are two efforts in the respective to the outputs: C_{2X} - the effort for academic research X, and (C_{2Y}) - the effort for commercial research Y.

The effort C_2 can be interpreted as the time spent on the activities. The total time for working varies within the researcher's disposal working time $\overline{C_2}$.

$$C_{2x} + C_{2Y} = \overline{C_2} \qquad (1)$$

Generally, the limitation can be extended, for instance, when some part of the work is outsourced i.e. the effort can be purchasable if the researcher can access a fund. For the

[2] Frey and Oberholzer-Gee (1997) p.746: Human behavior is influenced by both *extrinsic* and *intrinsic* motivation. The former is activated from the outside. In particular, individuals follow the generalized law of demand. Intrinsic motivations, on the other hand, relate to activities one simply undertakes because one likes to do them or because the individual derives some satisfaction from doing his or her duty.

researcher, a favourable joint project will occupy his minimal effort but still leaves a considerable budget for him to use in academic research (for example, buying outsource effort for his own academic research). It also offers him useful hints (for example, scientific research topic) for his academic research.

Moreover, the competence C_1, in general, will grow over time through the endeavour C_2 of the researcher. As a result, when there is no supporting research fund, with $f(\cdot)$ as the voluntary training function, we describe the growth of the competence C_1 as follows:

$$C_{1x} = C_{1X(0)} + f_X(C_{2X}) \quad (2)$$
$$C_{1Y} = g(C_{1X(0)}) + f_Y(C_{2Y}) \quad (3)$$

- *Contribution* (C_3): finding meaning (or intrinsic motivation) in the work we do.

Obviously, researchers are happy to contribute his scientific work towards the society with or even without financial reward. For example, it may be for the prestige, or is to satisfy his intellectual curiosity personally as well as the desire for doing good socially. It may be simply because he likes to do it. It is natural to demonstrate this intrinsic motivation as an increasing function $\chi(\cdot)$ of the value[3] obtained from the research output X and Y.

$$C_{3X} = \chi(X) \quad (4)$$
$$C_{3Y} = \chi(Y) \quad (5)$$

It is logical to think that the intrinsic motivation C_3 has a positive correlation with the respective effort C_2. As a result, when there is no supporting fund, with $\theta(\cdot)$ as an increasing function, we can demonstrate them as follows:

$$C_{2X} = \theta(C_{3X}) \quad (6)$$
$$C_{2Y} = \theta(C_{3Y}) \quad (7)$$

2. The more the researcher generates X and Y, the more he feels satisfied, that is, the higher his utility[4] U of X and Y is.

[3] For simplicity, we define the values of the research and as and respectively.

[4] We are aware that the economic concept of utility as generally applied today is *outcome-oriented*. As researcher's utility function is actually a function of C_3 - finding the meanings of doing an activity, it also implies that the individual simply undertakes that activity because he likes to do it, or because he derives some satisfaction from doing his activity. Indeed, it is *preferences over actions* which is critically different from *preferences over outcomes* (Frey and Oberholzer-Gee, 1997; Frey et al., 2004). However, there are no problems in our paper owing to the fact that we define C_3 as a function of the outcomes X and Y.

2.3. Mathematical Expression of the Model

2.3.1 Forms of academia-industry relations

There are various forms of relations between academia-industry (Table 2) as well as several types of research grants. As a result, the researcher is expected to adjust his behaviour to optimize his utility depending on the combination of his collaboration forms and grant types.

Table 2.
Forms of academia - industry relations (Link et al., 2007; Perkmann et al., 2011)

Licensing	Contractual assignment of university-generated intellectual property (such as patents) to external organizations
Academic entrepreneurship	Development & commercial exploitation of technologies pursued by academic inventors through a company they (or partly) own
Collaborative research	Research jointly pursued by university and industrial partners commonly with public funding
Contract research	Application-oriented research and development activities carried out by university commissioned and funded by industry
Consulting	Application-oriented research and development activities or advice provided individually by academics commissioned and funded by industry

2.3.2. Effects of Research Grants

Public and industry funds have different impacts on research output: (Bozeman and Gaughan 2007) indicated that grants and contracts from industry have a significant effect on academic researchers propensity to work with industry. In turn, public grants also have an impact in increasing work with industry, but a more moderate scale. Grimpe

(2012) studied six types of public and industry research grants in Germany and found that scientist productivity measured in terms of publication and patent stock is a statistically significant determinant only for obtaining foundation and industry grants while the award of an FP6 or government grant is influenced by other characteristics. Hottenrott and Thorwarth (2011) found some negative effects that a higher budget share from industry reduces publication output of professors both in terms of quantity and quality in subsequent years. However, industry fund has a positive impact on the quality of applied research if measured by patent citations.

2.3.3. Integrating Industry Research Funds into the Model

In this paper, since we are interested in the academic researcher's behaviour towards the collaboration of academia-industry, public fund is temporarily excluded in the present setting.

Industry gives the researcher a research grant to obtain his commercial research output Y. Therefore, the grant amount is a function of the value of Y, that is, $M(Y)$. The researcher allocates the grant at will to increase his $C_{1x}, C_{1Y}, C_{2X}, C_{2Y}$.

The allocation amount is
$M_{1x}, M_{1Y}, M_{2X}, M_{2Y}$ respectively.

The ultimate aim of an academic researcher is to optimize his utility function. He will choose his optimizing targeting levels of competence C_1 and effort $C_2$by "purchasing" necessary amounts of them. For instance, the researcher can hire other competent researchers, or outsource the tedious task of inputting data.

The parameters $\alpha_{1x}, \alpha_{1Y}, \beta_{2X}, \beta_{2Y}$ are the effect of one money unit on $C_{1x}, C_{1Y}, C_{2X}, C_{2Y}$ respectively.

$$\max_{C_{1X},C_{1Y},C_{2X},C_{3X}} U\begin{pmatrix} X(C_{1X}, C_{1Y}, C_{2X}, C_{3X}), \\ Y(C_{1X}, C_{1Y}, C_{2Y}, C_{3Y}) \end{pmatrix}$$

s.t.

$$C_{1X} = C_{1X(0)} + f_x(C_{2X}) + \alpha_{1X}M_{1X}$$
$$C_{1Y} = g\left(C_{1X(0)}\right) + f_Y(C_{2Y}) + \alpha_{1Y}M_{1Y}$$
$$C_{2X} = \theta(C_{3X}) + \beta_{2X}M_{2X}$$
$$C_{2Y} = \theta(C_{3Y}) + \beta_{2Y}M_{2Y}$$
$$C_{3X} = \chi(X)$$
$$C_{3Y} = \chi(Y)$$
$$\theta(C_{3X}) + \theta(C_{3Y}) = \overline{C_2}$$
$$M(Y) = M_{1X} + M_{1Y} + M_{2X} + M_{2Y}$$

3. Analysis Results and Implications

For the simplicity, we will focus on two simple scenarios to examine our framework: 1) there is no supporting research fund for the researcher, 2) there is a supporting public grant to use without any restriction.

3.1. Case 1

There is no supporting research fund for the researcher

$$\max_{C_{1X},C_{2X}} U\left(X(C_{1X}, C_{1Y}, C_{2X}, C_{3X})\right)$$

s.t.

$$C_{1X} = C_{1X(0)} + f_x(C_{2X})$$
$$C_{2X} = \theta(C_{3X}) \leq \overline{C_2}$$
$$C_{3X} = \chi(X)$$

Since $U(\cdot)$ function, $X(\cdot)$ function, $\theta(\cdot)$ function and $\chi(\cdot)$ function are increasing functions with respect to their own variables, it is easy to see that the optimizing solutions are as follows:

This is the simplest case. When there is no supporting fund, to optimize his utility, the researcher just conducts his work with all his effort.

3.2. Case 2

There is a supporting fund to use without any restriction. The fund amount is $\overline{M}$ (a fixed value).

$$\max_{C_{1X},C_{2X}} U\left(X(C_{1X}, C_{1Y}, C_{2X}, C_{3X})\right)$$

s.t.

$$C_{1X} = C_{1X(0)} + f_x(C_{2X}) + \alpha_{1X}M_{1X}$$
$$C_{2X} = \theta(C_{3X}) + \beta_{2X}M_{2X}$$
$$C_{3X} = \chi(X)$$
$$M(Y) = M_{1X} + M_{2X}$$

It is obvious that $\theta(C_{3X})$ will equal to its maximum value $\overline{C_2}$. Like in the previous case, it implies that to optimize his utility, the necessary condition is that the researcher will carry out his work with all his effort. However, since there exists a supporting fund, how should the fund be allotted to make full use of it?

The Lagrangian equation $L(C_{1X}, C_{2X}, \lambda)$ for this optimization problem is defined as

$$L(C_{1X}, C_{2X}, \lambda) = X(C_{1X}, C_{2X}, C_{3X}) + \lambda\left(\bar{M} - \frac{C_{1X} - \left(C_{1X(0)} + f_X\right)}{\alpha_{1X}} + \frac{C_{2X} - \overline{C_2}}{\beta_{2X}}\right)$$

The condition for optimization is as follows:

$$\frac{\partial X/\partial C_{2X}}{\partial X/\partial C_{1X}} = \frac{\alpha_{1X}}{\beta_{2X}} - \frac{\partial f_X}{\partial C_{2X}}$$

The left-hand side of the above equation is the economic rate of substitution between C_{1X} and C_{2X}.
Alternatively,

$$\frac{\alpha_{1X}}{\beta_{2X}}\frac{\partial X/\partial C_{1X}}{\partial X/\partial C_{2X}} = 1 + \frac{\partial f_X}{\partial C_{2X}}\frac{\partial X/\partial C_{1X}}{\partial X/\partial C_{2X}}$$

Notice that $\alpha_{1X}\frac{\partial X}{\partial C_{1X}}$ and $\beta_{2X}\frac{\partial X}{\partial C_{2X}}$ are the marginal research output of money spent on C_1 and C_2 respectively.
In most of cases, since $\frac{\partial f_X}{\partial C_{2X}}$ is positive, it implies that at the state of optimization, comparing with the money spent on research effort, money spent on research competence gives a higher value of research output. $f_X(C_{2X})$ is the voluntary training function that demonstrates the effect of the effort C_{2X} accounting for substantial changes (usually, the increase) in the competence C_{1X}.

Furthermore, making a comparative static analysis of $M_{1X}(C_{1X}, f_X)$ and $M_{2X}(C_{2X})$, we found that if $\frac{\partial f_X}{\partial C_{2X}}$ is low, researchers tend to increase money to "purchase" more research effort C_2. In contrast, more money will be allotted for "purchase" research competence C_1 if $\frac{\partial f_X}{\partial C_{2X}}$ is high.

4. Conclusions and Discussion

When there is no research fund provided, the researcher will conduct his work with all his effort to optimize his utility. However, if public fund is provided to facilitate the researcher's work, he/she will tend to use the fund to improve his/her research competence rather than spend on research effort. In general, academic researchers will conduct both academic and commercial researches even without research fund on the condition that researchers are free to choose how to engage in commercial research. If commercial research is set as a compulsory task, both obtained utility and long-term academic output are lower than ones obtained when they are free.

This study treats the concept of human resource in a broader scope than a firm's own human resource at traditional intra-organizational level. Open innovation increasingly plays an important role in R&D. In particular, escalating costs and shorter time in R&D are driving many firms to seek collaborations with academia to stimulate innovation. Companies are expected to not only organize their internal human resource efficiently, but also manage the "external" human resource smartly. In reality, despite amble opportunity to work together with academia, companies cannot capture the full potential of such relationships. What caused the failure? As mentioned in this paper, perhaps that is about a distinctive difference in human resource working for companies and those for universities who, different from company engineers or researchers, have multiple complex motivations and instinct attributes that seem to be obscure to companies. Companies must have a different approach to manage and make use of this kind of external human resource in technology management. The first step is

that companies need to understand the academia researcher's behavior and his/her process of decision-making. This paper has offered some theoretical insights for that first step.

The results of this research have shed light on difficulties and challenges for companies who want to make good use of the external academia human resource. Some of them are as follows. Firstly, companies must have an effective strategy to compete with public funds in enticing researchers into company research. Secondly, even with an ample commercial fund provided by companies, academia researchers tend to use it to improve their research competence rather than spend on the research itself. Companies therefore need an appropriate collaboration schedule to "oversee" the research performance, or they must find ways to integrate the improvement of researcher competence into the project as a goal of the collaboration. Thirdly, as academic researchers tend to prioritize their freedom in research, companies sometimes should not strictly "oversee" but smartly "follow up" on the project. Finally, as researcher's self-interests might be too strong to manage in some cases, companies may need to think of building a network or a consortium of several universities that focus on a same specific topic. Creating such a cooperative competition (co-opetition) among academia researchers may reduce undesired effects in collaborating with just a few handful of academia researchers.

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