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The Longitudinal Impact of Academic Patenting on Publishing Behavior: Evidences from Taiwan (2001-2010)

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Abstract--**The paper examines the longitudinal impact of academic patenting on faculty's publication in order to figure out the relationship between industry engagement and public knowledge production. There are few comprehensive and longitudinal studies to investigate the issue. The research framework are elaborated not only patenting behavior in terms of involvement, productivity, and experience, but also publication characteristics in terms of quantity, quality, and orientations. Based on a panel dataset (2001-2010) from 377 faculties at National Tsing Hua University. The results indicate that academic inventors outperform non-inventors in quantity, quality, applied/basic journal publication, and find a reinforcing effect of academic patenting on publication.**

I. INTRODUCTION

The role of university in society is changing in the recent past [1-3]. Contributing to industrial innovation are increasingly complemented teaching and research [4-6]. It concerns not just only explorative the understanding in scientific knowledge but also problem solving and exploitation of knowledge in industry [1, 2, 7-9].

In consequence, there are emerging new modes of governance on academic research outcome. Patenting, licensing, technology transfer, University- Industry (U-I) collaboration, consulting, and spin- off are examples of such new governance means [10-13]. Such ownership-based knowledge production obviously is in contradiction with traditional mandate of public knowledge sharing. It is expected to have influence on the incentives for academic research [14-16]. Therefore, it is no doubt that a lot of research concern negative side effect of industry engagement on free and open academic research, such as Heller and Eisenberg [17], Thursby and Kemp [16], Nelson [18], Murray and Stern [19], Zeebroeck, et al. [20], Franzoni and Scellato [21], and so on. As the result, the faculty may reduce the quantity of public disclosure, limit the generality, and change the orientations on academic research. In long-term, it may lead to inhabit public flow of scientific knowledge and hinder following discoveries [17, 19].

One of those approaches, Inventor-Author Analysis, focuses to use inventor-author data to explore the impact of being jointly involved in patenting and journal publishing on faculty's performance [22, 23]. Those studies often employ long-term bibliometric analysis of shifting patent filing to examine the influences on journal publication.

Although there are many studies have already examined the contradiction between academic patenting and publication performance, we still don't have convergent results. The existing studies found that the relationship between academic patenting and publication performance could be positive [24-26] , irrelevant [27, 28],or negative [29, 30]. Three potential reasons result in these divergent results. First of all, the differences of sampling on disciplines, organizations, and groups, would cause the bias on validity of results[31]. Second, differences of patenting behavior are considered such as individual difference [25, 32], involving timing [30, 32], or activity intensity [24, 27]., is another major reason to lead inconsistent results. Third, the different measures of publication performance are discussed such as quantity [24, 27, 30], quality [26, 28, 33], or types of research [25, 26, 28], have different responses to academic patenting. To harmonize the divergent results, it need a complete framework to systemically investigate the multidimensional patent-publication relationship.

Based on the above, the aim of this paper is first to consolidate the explanatory-variables and study designs from studies reported in literature and second to frame a multi-dimensional examinations. In the next sections, explanatory variables and study designs are discussed based on the literatures. This is followed by the report of the empirical study from panel data analysis on journal publication publishing and patenting of the faculty in National Tsing Hua University, Taiwan (NTHU) between 2001 and 2010. Then, the results are discussed. In the final, we conclude there is no anti-common effect on academic patenting to publishing behavior as same as prior research. And, academic patenting is benefit to promote faculty's publishing behavior at least in the Taiwanese university context.

II. STUDIES ON THE IMPACT OF ACADEMIC PATENTING ON PUBLISHING BEHAVIOR

A. Academic patenting behavior and publishing behavior

In last decade, many studies attempt to employ bibliometric analysis to investigate the impact of academic patenting on publishing behavior. A variety of metrics are compiled as the indicator of behavioral descriptions. [24, 34].

There are three major patenting behavioral designs on explanatory variable compilations that include *involvement*, *productivity*, and *experience*.

In other side, there are three major measures on publishing behavior, *quantity, quality* and *orientation* in prior studies.

In the recent past, several studies (Table 1) employed different indicators on academic patenting to measure its relationship with the change on the quantity, quality, and orientations of faculty's publishing behavior.

B. Patenting involvement and publishing behavior

Patenting involvement is qualitative variable that describe engagement into academic patenting different timeframes. The first patenting measurement qualifies the faculty as inventor who is involved in patenting. Impact on publishing behavior is analyzed as statistical test whether the impact of academic patenting exist or not. Van Looy, et al. [25] compared faculty's annual counts of journal publication and basic/applied journal publications within the inventor and non-inventor groups in Catholic University of Leuven. The study showed that the inventors have more publications, as well in basic journals than their colleagues. However, there was no significant difference on applied journal publications. Fabrizio and Di Minin [30] collected 300 faculty records from US's universities during 1975 to 1995. They found that the inventors have higher annual number of publications and are more often cited. Buenstorf [32] compared 140 inventors and 174 non-inventors who have worked at Max Planck Society in Germany between 1985 and 2004. The study indicated that inventors have more publications, but did not show a relationship to citations.

A distinct, dynamic, use of the variable "involvement" is the distinction between non-involved, pre patenting periods and the post patenting periods after the first patent filing. Breschi, et al. [26] set an empirical dataset, from the 592 professors in Italian Universities between 1980 and 1999. The results showed the faculty has more publications as same as the findings in Van Looy, et al. [25] and Azoulay, et al. [28], and they also have more received citations and basic journal publications after involving into academic patenting.

A third use of the variable involvement is the distinction between years, in which an author has firstly patented. In the other words, it measures primacy change on publishing behavior from non-patenting to patenting. In Breschi, et al. [26] study, the inventors seemed to have no significance on their publication counts and basic journal publication counts, but cumulated citations were positively significant in the year when they filed the first patent.

Finally, the last variable involvement, is the distinction between years, in which an author has at least one patent filed. Azoulay, et al. [28] employed the case from 3,862 life scientists in the US between 1968 and 1999. They found that journal publication counts, weighted by journal impact factor, in high commercial score journals are positively related with years with patent filing. Crespi, et al. [35] established a panel data for 157 researchers in UK's universities from 1975 to 2005. The study found that publication counts are not significantly different in patenting years and non-patenting years.

C. Patenting productivity and publishing behavior

Productivity is a quantitative measure of academic patenting. It is annual counts of patent filing. Several relationships of patenting productivity on publishing behavior are defined as, crow-out, irrelevance, co-existence, and enforcement. For example, Agrawal and Henderson [24] employed the data of 236 faculty from MIT between 1983 and 1999. They found co-existence that the number of journal publication and faculty's received citations are not significantly correlated with patenting productivity. Czarnitzki, et al. [24] collected the records between 1998 and 2002 of 3,135 inventors who are faculty of German's universities. They found an enforcement effect that the inventors produce more publications and more frequent citation of work prior to patenting, and Buenstorf [32] confirmed this findings. Wang and Guan [33] confirmed enforcement in panel data based study of 6,321 academic nanotechnology inventors in China between 1991 and 2008. Through the regressions, annual publication counts and publication counts weighted by journal impact factor were positively related with patent filing counts in the same year.Kelchtermans and Veugelers [29], in contrast, found significant but weak negative correlation between patenting productivity and publication quantity in data about 1034 faculty in Catholic University of Leuven, Belgian, between 1992 and 2001. But, the patenting productivity is positively related with citations of journal publications in the same year, and Fabrizio and Di Minin [30] have the same finding.

D. Patenting experiences and publishing behavior

Patenting experience is a combined variable of the above two variables. It is the accumulation of patenting productivity over all years, or the cumulated patent count for an inventor. It is a long-term behavioral measurement. In Czarnitzki, et al. [24], it showed that the faculty have more journal publications and higher impact factor wieghted counts after the first patent year. Azoulay, et al. [28] found that the cumulated journal publication count is positively related to the cumulated patent. In contrast, Crespi, et al. [35] did not find significant relationship. And, Fabrizio and Di Minin [30] even found a negative relationship between patenting experience and citiations received in post patenting years.

E. The impact of academic patenting on publication: Toward a multi-dimensional framework

From the above, most of studies have confirmed the engagement of academic patenting may influence publishing behavior, but they are diversified on quantity, quality, and orientations. Moreover, because of a variety of compilations on patenting variables, the results are showed many observations. Obviously, integrating into multi-dimensional framework (**Fig.1**) is benefit to piece out the whole picture. For example, the four involvement variables identify unobserved changes on publishing behavior when the faculty start to engage, in the engaging, and after the engagement [25, 26, 28, 32, 35]. Combining those observations could provide an overview of the impact on publishing behavior through the time.

In addition, multiple-variables examinations also could avoid overestimating the impact when the estimations only employ one kinds of variables [26, 28]. In next section, the paper would employ new panel data of National Tsing Hua University in Taiwan between 2001 and 2010.

TABLE 1 IMPACT EXAMINATIONS IN DIFFERENT PATENTING-BEHAVIOR COMPILATIONS ON PUBLISHING BEHAVIOR[A]

Explanatory variables	Relationship to faculty's annual journal publication behavior			
Patent	Quantity	Quality	Orientations (Journal orientation)	
			Applied	Basic
Involvement				
Inventor and non-inventor	Van Looy et al. (2006) (+) Fabrizio and Di Minin (2008)(+) Buenstorf (2009)(+)	Fabrizio and Di Minin (2008)(+) Buenstorf (2009) (x)	Van Looy et al. (2006) (x)	Van Looy et al. (2006) (+)
Post patenting years	Van Looy et al. (2006) (+) Fabrizio and Di Minin (2008) (+) Breschi et al. (2008) (+) Azoulay et al. (2009) (+)	Breschi et al. (2008) (+)		Breschi et al. (2008) (+)
First patenting year	Breschi et al. (2008) (x)	Breschi et al. (2008) (+)		Breschi et al. (2008) (x)
Patenting year	Azoulay et al. (2009) (+) Crespi et al. (2011) (x)	Azoulay et al. (2009) (+)	Azoulay et al. (2009) (+)	
Productivity				
Annual counts of patent filing	Agrawal and Henderson (2002) (x) Czarnitzki et al. (2007)(+) Fabrizio and Di Minin (2008) (+) Buenstorf (2009)(+) Wang and Guan (2010) (+) Kelchtermans and Veugelers (2011)(-)	Agrawal and Henderson (2002) (x) Czarnitzki et al. (2007)(+) Fabrizio and Di Minin (2008)(x) Buenstorf (2009) (+) Wang and Guan (2010) (+) Kelchtermans and Veugelers (2011)(+)		
Experience				
Cumulated counts of patent filing	Azoulay et al. (2009) (x) Crespi et al. (2011) (x)	Fabrizio and Di Minin (2008)(-)		
Cumulated Post-patenting year	Czarnitzki et al. (2007)(+)	Czarnitzki et al. (2007)(+)		

a. "+" indicates significantly positive, "-" significantly negative; "x" not significant

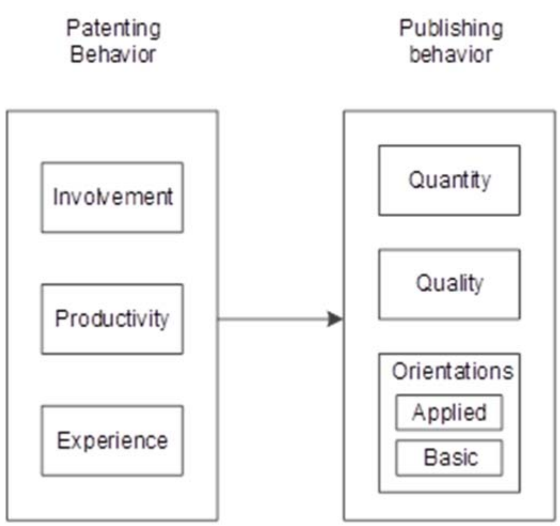

Figure 1 Analytical Framework for the Impact of Academic Patenting on Publishing Behavior

III. AN OVERALL VIEW OF NATIONAL TSING HUA UNIVERSITY, TAIWAN

A. Background, Patenting, and Publishing

National Tsing Hua University (NTHU) is founded in 1911 and re-established to Hsinchu in Taiwan in1956. In 2012 academic year, there are 651 faculties and 12,059 students, and it includes 41 departments or institutes and 7 schools in Science, Engineering, Electrical Engineering and Computer Science(EECS), Life Science, Nuclear Science, Humanities and Social Science, and Technology management. According to 2012-2013 Times High Education Supplement's World Universities Rankings, NTHU is listed between 266 to 250, and is also listed in 192 and 258 in QS World University Rankings (QS) and Shanghai Jiao Tong University's Academic Ranking of World Universities (ARWU).

B. Sample

In order to exanimate the impact of academic patenting, the study constructs a panel dataset, Triple-P (TP), during 2001 to 2010, includes personnel data from faculty's biography, and bibliometric data from the patent filings and journal publications. According to NTHU official personnel list in 2010, there are 615 full-time faculties. At the beginning, the sample excludes the faculty from Humanities and Social Science School and Technology Management School which the knowledge is not easy to patent [39]. It remains 445 faculties from 5 schools, then excludes 68 faculties after checking personnel, patent and publication records. They don't have any patent and publication records in selected database during 2001 to 2010. In the final, TP has 377 faculties are shared 84.72% and 61.31% of faculty number from 5 schools and whole university (Table 2).

TABLE 2 DEMOGRAPHICS OF SAMPLE FACULTY (IN 2010)

School	Professorship			Total
	Assistant	Associate	Full	
Science	5	18	57	80
Engineering	3	14	95	112
EECS	4	40	57	101
Life Sc.	2	10	24	36
Nuclear Sc.	3	14	31	48
Total	17	96	264	377

In the part of patent data, TP collects the data from public information from patent office. Considering the localization, TP select that patent filing at TWPO and USPTO until 2010. During sample period, it is total 2,462 patents associated with NTHU's faculty, and 1,497 TWPO patents and 965 USPTO patents. After combining the patents with priority claim, there are 1,909 patent filings, and 207 faculties have patenting records, and are shared 54.91% of the sample.

In publishing behavior, TP adapts the publications in the journal which are listed in SCI list as the observations. The reason why TP choose journal publications in this database is that it has more comprehensive and long-term bibliometric data. TP retrieves the data from Taiwan Science and Technology Policy and Information Research Center (STPI) which has a database that collects bibliometric data from ISI Web of Sciences, and integrates journal bibliometric data to each journal publications, such as journal category, journal impact factor, journal ranking, and so on. And, TP follows prior researches, such as Van Looy, et al. [40], Calderini, et al. [41] ,and Breschi, et al. [27],to apply journal classifications of Hamilton [42] as the nature of publications [43]. The study retrieves publication records from 2001 to 2010 by locking in the affiliation of authors that is National Tsing Hua University. In the primary, 10,894 publication records are found, then TP excludes journal publications are book reviews, edition notes, book chapters, and proceedings. In next step, TP build personal publication records by matching manually the names and affiliations of sample faculty in each publications. Third, the total of counts is 8,401 journal publications, and TP identifies the nature of publications based on journal title. In the final, there are 8,169 journal publication counts are classified, and non-classified counts are 232 and shared 2.76% of total counts.

C. Dependent Variables

In the measurements of publishing behavior, this study has three types of variables, quantity, quality, and orientations. In the quantity, TP counts annual journal publications as Paper.Num_{it} are created. In the quality, although the citations are well utilized to measure the quality, the study concerns the inflations on publishing year and faculty's career age, so TP adapts another alternative that employs publication counts weighted by journal impact factor in publishing year [29, 31, 41, 44]. $\text{Paper.JIF.Num}_{it}$ are employed the quality of publishing behavior. In the final, TP counts the nature of publications at the both of classifications, and $\text{Paper.Basic.Num}_{it}$ and $\text{Paper.Applied.Num}_{it}$ are hired to measure the orientations.

D. Explanatory variables

1) Patenting Involvement

In term of qualitative impact measurement, this study elaborates different involvement measurements to examine faculty publishing behavior in sample period. Those variables are dummy variables with different timeframes. Inventor_i mark the years equal to 1 in whole years when faculty have patent filing in their faculty career during 2001 to 2010, otherwise 0. And, $\text{P.Patent.Year}_{it}$ equal to 1 that mark the years after first patent filing, otherwise 0. In snap-shot measurements, $\text{F.Patent.Year}_{it}$ equal to1 that mark the year is faculty's first patenting year, otherwise 0. And, Patent.Year_{it} equal to 1 that mark the years when faculty has at least one patent filing, otherwise 0.

2) Patenting Productivity

Aside from the involvements, the productivity is another important measurement. In this variable compilation, there are different two designs in prior researches, $\text{Patent.Num}_{i,\ t-1}$ and Patent.Num_{it}, are annual counts in last and current year. The difference is based on journal publishing delay in time that the publications are counts in publishing year but patent are counts by filing year [26, 30]. However, in the case of NTHU, most of faculty doesn't have too much knowledge for patent filing, and always need the assists from patent agency and TTO. And, the faculty still takes a lot of time on assessing the prior art, discussing the claims, finishing the documents, following the schedule of TTO, and so on. It also exists the delay of time window. Under this concern, the measurement on patenting productivity is $\text{Patent.Num}_{\text{it}}$ that it closes more the situations in NTHU.

3) Patenting Experience

Combining the involvement and productivity, the experience variables are estimated cumulated effect on academic patenting, but also are showed the impact of patenting career to reshape publishing behavior. In the study, Patent.C.Num_{it} is counted by cumulating patent counts of faculty i until last year as the accumulations in current year. And, we also employ $\text{Patent.C.Year}_{it}$ as experience measurement which is counted by cumulating patenting years of faculty i until last year as the accumulations in current year.

E. Control Variables

In following regression analysis, the study applies a pre-test on personnel variables to publish behavior, including the sexual, school, professorship, faculty age, PhD degree, the square of faculty age and new employee after 2001

(Appendix, Table 3). New employee after 2001, faculty age, and the square of faculty age are also significantly related to publishing behavior, and they are taken into account as control variables. And, the measurement in publishing quality is counted by weighting journal impact factor that high related to basic and applied journal classification, so $\text{Paper.Basic.Num}_{it}$ is controlled when dependent variable is $\text{Paper.JIF.Num}_{it}$ specifically. The definitions of all variables are in the appendix.

IV. RESULTS

A. Descriptive statistics

In TP dataset, there are total 377 faculties, and the number of inventor is 207. In personnel data, the male shares 88% of sample faculty, and the average of faculty age is 12.25 years, then 162 faculty joins NTHU after 2001(Appendix, Table 4). Moreover, there are 30% and 27% faculty from schools of Engineering and Electronic Engineering and Computer Science (EECS). The inventors have 0.88 patent filing per year in the average, and cumulate 3.05 patents per year. During 2001 to 2010, the inventors have average 4 active-years in the patenting and 6.5 years after first patent filing. And, the inventors have 1.51 cumulated years and 3.51 cumulated patents in the average. In publishing behavior, the average of publication counts per year is 2.15, and cumulate counts are 10.02 on full sample. The inventors have average 1.09 and 1.58 publications in applied and basic journals, and higher that non-inventors. But, basic journal publications are high than applied ones at the both, and it means that most of faculty in NTHU still pay more attentions to basic journal publishing.

B. Econometric regressions

In order to examine the impact of academic patenting to publishing behavior, this study employs panel negative binomial regressions in fixed effect model. TP compiles the variables by counts, and it is discrete and non-negative. In general, count data analysis could be estimated by Poisson model and negative binomial model. TP dataset combines the data from the inventors and non-inventors, and it exists the heterogeneity of population. From descriptive statistics, standard deviations are big than the mean in the variables by counted, it seems like over-dispersions. Considering the specification, the study choose negative binomial model as regression model, and follows prior similar studies, such as Azagra-Caro, et al. [39], Breschi, et al. [27], Crespi, et al. [32]. Moreover, because of unobserved heterogeneity that are constant over the time from faculty characteristics, the models run under conditional regressions in fixed effect (FE) model.

The study concerns a variety of patenting measurements provide more evidences on the impact of academic patenting to publishing behavior. At the first, the dummy of inventor is provide basic understanding the difference on inventor and non-inventor's publishing behavior from 2001 to 2010. It indicates that the inventors have more journal publications (β=0.57, p<0.01) and high publication's quality (β=0.37, p<0.01). On publication orientations, the inventors have more basic journal publication (β=0.55, p<0.05), and the coefficient of applied journal publication is positive but no significant (β=0.29). Second, we measure the change of faculty's publishing behavior after engaging in patenting, and the results shows that academic inventors positively enforce their publishing behavior on the quantity (β=0.28, p<0.01), quality (β=0.30, p<0.01), applied journal publication(β=0.39, p<0.01), and basic journal publication (β=0.21, p<0.01) after engaging in patenting.

Furthermore, the paper also concern primacy change in first patenting year. In the sample, there are 162 faculties file their first year during 2001 to 2010. It is an important time spot for involving new activity associated with third missions, and its results shows that there are positive growth on the quantity(β=0.05), quality (β=0.06), applied journal publication (β=0.14), and negative on basic journal publications (β=-0.03), but all of them are no significant. It seems that there are no too much changes on publishing behavior when the faculty intends into academic patenting. Continuously, we compare publishing behavior on patenting and non-patenting years, and it shows that publishing behavior in patenting year are significantly positive related to academic patenting stand on the quantity (β=0.13, p<0.01), quality (β=0.15, p<0.01), and applied journal publications (β=0.12, p<0.05) to basic journal publications (β=0.16, p<0.01).

In addition, this paper also measure quantitative impact of academic patenting on publishing behavior, and the impact is measured by the examinations on annual patent filing counts to journal publication counts. And, we find the inventors have more journal publication number (β=0.03, p<0.01), higher quality (β=0.05, p<0.01), applied journal publications (β=0.04, p<0.05), and basic journal publications (β=0.03, p<0.1). The results are not only consistent with the examination on qualitative impact, but also indicate that, there are no trade-off between patenting and publishing behaviors in the same year.

Besides the above, patenting experience are employed measure the impact of long-term faculty involvement. Cumulated patenting years measure the impact to publishing behavior by increasing the years in post patenting years, and the results find that applied journal publications of faculty is significantly negative (β=-0.05, p<0.05), and publication's quality is significantly positive (β=0.06, p<0.01), and other variable have no significant changes on publication quantity (β=-0.01) and basic journal publication counts (β=0.01). On another measurement, cumulated patent counts are hired, the estimations show the same result with the former on publication quantity (β=-0.003), quality (β=0.01, p<0.01), applied journal publication (β=-0.01, p<0.1), and basic publication (β=0.004). Based on two observations, we could find the inventors have high quality in their publications but they would not publish more applied journal publication when they have more experience on academic patenting. Table 5 summaries all estimations.

TABLE 2 RESULTS OF REGRESSIONS: GENERAL PATENTING BEHAVIOR ON PUBLICATION [a]

Independent variables	Relationship to faculty's annual journal publication counts[b]			
	Quantity	Quality	Orientations	
			Applied	Basic
	$Paper.Num_{it}$	$Paper.JIF.Num_{it}$	$Paper.Applied.Num_{it}$	$Paper.Basic.Num_{it}$
Involvement				
$Inventor_i$	+***	+***	+	+**
$P.Patent.Year_{it}$	+***	+***	+***	+***
$F.Patent.Year_{it}$	+	+	+	-
$Patent.Year_{it}$	+***	+**	+**	+***
Productivity				
$Patent.Num_{it}$	+***	+***	+**	+*
Experience				
$Patent.C.Year_{it}$	-	+***	-**	+
$Patent.C.Num_{it}$	-	+***	-*	+

a. Full results are in the Appendix(Tables 8-11)

b. The signs report the coefficient is positive "+" and negative "-" in the models, and the number of sign report significant level stand on* p<0.1, ** p<0.05f, *** p<0.01.

V. DISCUSSION

In this study, it succeeds prior researches which measures the impact of academic patenting by employing a novel panel dataset from NTHU in 2001 to 2010. In this case, we measure the relationship within academic patenting and publishing behavior by elaborated by different patenting measurements and more discussions on publishing behavior in term of quantity, quality, and orientations. It doesn't just attempt to provide more micro evidences, but also tries to figure out more answers on patent-paper examinations.

First, the question is whether academic patenting reduce faculty's publishing productivity and quality or not. The debate thinks that the disclosure delay or secrecy lead to the decrease of public publications. And, more patenting make faculty's research too close the practice, and the generality of research is limited to specific problem solving, and lead to constrain its quality [19, 21, 36, 37]. In the case of NTHU, we find positive changes from several examinations. The inventors outperform on journal publication publishing in term of quantity and quality during 2001 to 2010 as same as Van Looy, et al. [25], Breschi, et al. [26], Fabrizio and Di Minin [30], Azoulay, et al. [28], and Buenstorf [32], and they sustain to promote the behavior after engaging into academic patenting no matter the year has patent filing or not. Moreover, the inventors have no trade-off within patenting and publishing behavior in the same year.

The second question is that whether academic patenting compress basic research or not. The debated concern that academic patenting make the faculty turn to focus on technology oriented or applied research in order to exploit commercial value, and lead to the decrease of basic research. In our examinations, and the finding is no effect as same as Breschi, et al. [26] and Thursby and Thursby [38]. NTHU is just like most of research universities that focus on fundamental research in science and technology. Although academic patenting are rising in the campus, academic inventors still always keep their basic research, and it doesn't influence by the increase of patenting and patenting experience. On other hands, the question is that whether applied research are increasing in academic patenting or not. From the results, it is definitely true that the faculty would increase applied journal publications in patenting years as same as other third mission activities, such as U-I collaborations [39, 40], and licensing [41].

Third, the question is that whether it has the possibility that academic patenting change faculty's publishing behavior when they have long-term involvement. Nelson [10] concerns the university would keep market research away from fundamental research because long-term academic patenting makes the benefits on the funding. And, Fabrizio and Di Minin [30] find that the inventors would low publication quality by repeat patenting. In our study, although we could find the inventors change their publishing behavior in academic patenting, they would not change their publishing behavior no matter how many experience in the year or number they have. Moreover, we confirm that the inventors may keep better publishing quality by increasing patenting experience.

VI. CONCLUSION

Under new mode of knowledge production, the university and faculty are encouraged to promote third mission, and create new academic paradigm. For university faculty, academic patenting is really new knowledge production that don't focus only on knowledge exploration, but also on how to improve existed problems by knowledge exploitations. In the case, NTHU just like most of universities focus on scientific researches on the before, and it also faces the same challenges now. In past 10 years, academic patenting and publishing are increasing continuously at the same time.

Based on the multi-dimensional analysis in NTHU, we conclude that it doesn't exist skewing choice between patenting and journal publication publishing for the faculty. Furthermore, academic patenting could enhance faculty's publishing behavior in term of quantity and quality. And, the faculty would not intend to less basic research on knowledge creation, but increase more works on knowledge exploitation by patenting filing and applied journal publications.

In this paper, we contribute the examinations between patenting and publishing behavior by combining prior researches, and explore the approach to a holistic framework. It doesn't just provides more systematic evidences by elaborating different patenting measurements, but also clarify the impact of academic patenting by the comparisons. However, the heterogeneity of patenting and publishing behavior are not discussed in this paper, and it maybe find out more interesting findings from future research.

REFERENCES

[1] J. Lubchenco, "Entering the Century of the Environment: A New Social Contract for Science," *Science,* vol. 279, pp. 491-497, January 23, 1998 1998.

[2] M. Gibbons, "Science's new social contract with society," *Nature,* vol. 402, pp. C81-C84, 1999.

[3] B. R. Martin, "The changing social contract for science and the evolution of the university," in *Science and Innovation: Rethinking the Rationales for Funding and Governance*, A. Geuna, A. J. Salter, W. E. Steinmueller, and Y. E. Hoffman, Eds., ed Cheltenham: Edward Elgar Publishing, 2001, pp. 7-29.

[4] H. Etzkowitz, A. Webster, C. Gebhardt, and B. R. C. Terra, "The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm," *Research Policy,* vol. 29, pp. 313-330, 2000.

[5] B. R. Martin and H. Etzkowitz, "The origin and evolution of the university species.," *VEST Journal for Science and Technology Studies,* vol. 13, pp. 9-24, 2000.

[6] H. Etzkowitz, "Innovation in Innovation: The Triple Helix of University-Industry-Government Relations," *Social Science Information,* vol. 42, pp. 293-337, September 1, 2003 2003.

[7] A. B. Jaffe, "Real Effects of Academic Research," *The American Economic Review,* vol. 79, pp. 957-970, 1989.

[8] R. K. Merton, "The Matthew effect in science," *Science,* vol. 159, pp. 56-63, 1968.

[9] D. E. Stokes, *Pasteur's quadrant: basic science and technological innovation*: Brookings Institution Press, 1997.

[10] R. R. Nelson, "Observations on the Post-Bayh-Dole Rise of Patenting at American Universities," *The Journal of Technology Transfer,* vol. 26, pp. 13-19, 2001/01/01 2001.

[11] S. Shane, *Academic entrepreneurship: university spinoffs and wealth creation*: Edward Elgar, 2004.

[12] N. Baldini, "The Act on inventions at public research institutions: Danish universities' patenting activity," *Scientometrics,* vol. 69, pp. 387-407, 2006/11/01 2006.

[13] T. T. Aldridge and D. Audretsch, "The Bayh-Dole Act and scientist entrepreneurship," *Research Policy,* vol. 40, pp. 1058-1067, 2011.

[14] C. Renault, "Academic Capitalism and University Incentives for Faculty Entrepreneurship," *The Journal of Technology Transfer,* vol. 31, pp. 227-239, 2006/03/01 2006.

[15] Y.-C. Chang and P. Y. Yang, "The impacts of academic patenting and licensing on knowledge production and diffusion: a test of the anti-commons effect in Taiwan," *R&D Management,* vol. 38, pp. 321-334, 2008.

[16] J. G. Thursby and S. Kemp, "Growth and productive efficiency of university intellectual property licensing," *Research Policy,* vol. 31, pp. 109-124, 2002.

[17] M. A. Heller and R. S. Eisenberg, "Can Patents Deter Innovation? The Anticommons in Biomedical Research," *Science,* vol. 280, pp. 698-701, May 1, 1998 1998.

[18] R. R. Nelson, "The market economy, and the scientific commons," *Research Policy,* vol. 33, pp. 455-471, 2004.

[19] F. Murray and S. Stern, "Do formal intellectual property rights hinder the free flow of scientific knowledge?: An empirical test of the anti-commons hypothesis," *Journal of Economic Behavior & Organization,* vol. 63, pp. 648-687, 2007.

[20] N. v. Zeebroeck, B. v. P. d. l. Potterie, and D. Guellec, "Patents and academic research: a state of the art," *Journal of Intellectual Capital,* vol. 9, pp. 246-263, 2008.

[21] C. Franzoni and G. Scellato, "Academic Patenting and the Consequences for Scientific Research," *Australian Economic Review,* vol. 44, pp. 95-101, 2011.

[22] M. Meyer, "Are patenting scientists the better scholars?: An exploratory comparison of inventor-authors with their non-inventing peers in nano-science and technology," *Research Policy,* vol. 35, pp. 1646-1662, 2006.

[23] E. C. M. Noyons, A. F. J. van Raan, H. Grupp, and U. Schmoch, "Exploring the science and technology interface: inventor-author relations in laser medicine research," *Research Policy,* vol. 23, pp. 443-457, 7// 1994.

[24] D. Czarnitzki, W. Glänzel, and K. Hussinger, "Patent and publication activities of German professors: an empirical assessment of their co-activity," *Research Evaluation,* vol. 16, pp. 311-319, December 1, 2007 2007.

[25] B. Van Looy, J. Callaert, and K. Debackere, "Publication and patent behavior of academic researchers: Conflicting, reinforcing or merely co-existing?," *Research Policy,* vol. 35, pp. 596-608, 2006.

[26] S. Breschi, F. Lissoni, and F. Montobbio, "University patenting and scientific productivity: a quantitative study of Italian academic inventors," *European Management Review,* vol. 5, pp. 91-109, 2008.

[27] A. Agrawal and R. Henderson, "Putting Patents in Context: Exploring Knowledge Transfer from MIT," *Management Science,* vol. 48, pp. 44-60, January 1, 2002 2002.

[28] P. Azoulay, W. Ding, and T. Stuart, "The Impact of Academic Patenting on the Rate, Quality, and Direction of (Public) Research Output," *The Journal of Industrial Economics,* vol. 57, pp. 637-676, 2009.

[29] S. Kelchtermans and R. Veugelers, "The great divide in scientific productivity: why the average scientist does not exist," *Industrial and Corporate Change,* vol. 20, pp. 295-336, February 1, 2011 2011.

[30] K. R. Fabrizio and A. Di Minin, "Commercializing the laboratory: Faculty patenting and the open science environment," *Research Policy,* vol. 37, pp. 914-931, 2008.

[31] M. Perkmann, V. Tartari, M. McKelvey, E. Autio, A. Broström, P. D'Este, *et al.*, "Academic engagement and commercialisation: A review of the literature on university–industry relations," *Research Policy,* 2012.

[32] G. Buenstorf, "Is commercialization good or bad for science? Individual-level evidence from the Max Planck Society," *Research Policy,* vol. 38, pp. 281-292, 2009.

[33] G. Wang and J. Guan, "The role of patenting activity for scientific research: A study of academic inventors from China's nanotechnology," *Journal of Informetrics,* vol. 4, pp. 338-350, 2010.

[34] M. Meyer, "Does science push technology? Patents citing scientific literature," *Research Policy,* vol. 29, pp. 409-434, 2000.

[35] G. Crespi, P. D'Este, R. Fontana, and A. Geuna, "The impact of academic patenting on university research and its transfer," *Research Policy,* vol. 40, pp. 55-68, 2011.

[36] J. G. Thursby, R. Jensen, and M. C. Thursby, "Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities," *The Journal of Technology Transfer,* vol. 26, pp. 59-72, 2001/01/01 2001.

[37] N. Baldini, "Negative effects of university patenting: Myths and grounded evidence," *Scientometrics,* vol. 75, pp. 289-311, 2008/05/01 2008.

[38] J. G. Thursby and M. C. Thursby, "Has the Bayh-Dole act compromised basic research?," *Research Policy,* vol. 40, pp. 1077-1083, 2011.

[39] M. Gulbrandsen and J.-C. Smeby, "Industry funding and university professors' research performance," *Research Policy,* vol. 34, pp. 932-950, 2005.

[40] H. Hottenrott and S. Thorwarth, "Industry Funding of University

Research and Scientific Productivity," *Kyklos,* vol. 64, pp. 534-555, 2011.

[41] J. G. Thursby, M. C. Thursby, and S. Gupta-Mukherjee, "Are there real effects of licensing on academic research? A life cycle view," *Journal of Economic Behavior & Organization,* vol. 63, pp. 577-598, 2007.

APPENDIX. CONTROL VARIABLES AND DESCRIPTIVE STATISTICS

TABLE 3 DEMOGRAPHICS OF FACULTY'S CHARACTERISTICS AND PUBLISHING BEHAVIOR [a]

Independent variables Faculty's Characteristics	Dependent variables			
	Paper.Num$_{it}$	Paper.JIF. Num$_{it}$	Paper.Applied. Num$_{it}$	Paper. Basic. Num$_{it}$
Male	-0.341	0.110	0.201	-0.042
	(0.452)	(0.149)	(0.662)	(0.449)
Engineering	-0.107	-0.115	0.432	-0.928*
	(0.314)	(0.151)	(0.314)	(0.554)
Science	1.478**	0.032	0.081	0.688
	(0.623)	(0.165)	(0.830)	(0.695)
Life Science	0.270	-0.797***	-0.705	-0.478
	(0.514)	(0.178)	(0.950)	(0.643)
EECS	-0.080	-0.313***	0.767	-0.750
	(0.358)	(0.165)	(0.466)	(0.686)
AT.Career$_{it}$	3.126***	3.374***	2.263***	3.286***
	(0.286)	(0.299)	(0.300)	(0.368)
AE.Career$_{it}$	3.702***	3.944***	2.870***	3.770***
	(0.289)	(0.302)	(0.310)	(0.372)
Full.Career$_{it}$	3.497***	3.869***	2.435***	3.707***
	(0.291)	(0.302)	(0.308)	(0.373)
Faculty.Year$_{it}$	0.159***	0.152***	0.186***	0.145***
	(0.015)	(0.016)	(0.024)	(0.019)
Faculty.Year$_{it}^2$	-0.003***	-0.002***	-0.004***	-0.002***
	(0.000)	(0.000)	(0.001)	(0.000)
N.Faculty.2001	0.756***	0.756***	0.621***	0.720***
	(0.127)	(0.127)	(0.390)	(0.357)
Constant	-3.132***	-5.243***	-3.441***	-3.117***
	(0.607)	(0.369)	(0.845)	(0.778)
N of Obs.	3740	3740	2810	2930
N of Faculty	374	374	281	293
Log-likelihood	-4533.63	-6192.80	-2591.99	-2972.48
Wald χ^2	545.47***	750.71***	257.55***	323.35***
D.F.	11	11	11	11

a. Conditional FE negative binomial regression, *p<0.1, ** p <0.05,*** p <0.01

TABLE 4 DESCRIPTIVE STATISTICS

Variables	Full sample (Obs.=3770,N=377)				Inventor (Obs.=2070, N=207)		Non-inventor (Obs.=1770, N=170)	
	Mean	S.D.	Min.	Max.	Mean	S.D.	Mean	S.D.
Personnel								
Male	0.88	0.32	0	1	0.92	0.28	0.84	0.37
Engineering	0.30	0.46	0	1	0.39	0.49	0.18	0.39
Science	0.21	0.41	0	1	0.09	0.28	0.36	0.49
Life Science	0.10	0.30	0	1	0.09	0.29	0.10	0.30
EECS	0.27	0.44	0	1	0.32	0.468	0.20	0.40
Faculty.Year$_{it}$	12.25	9.16	0	37	12.66	8.57	11.74	9.82
Faculty.Year$_{it}^2$	233.92	262.49	0	1369	233.67	250.38	234.22	276.6
N.Faculty.2001	0.43	0.5	0	1	0.39	0.49	0.48	0.50
Patenting								
P.Patent.Year$_{it}$	0.36	0.48	0	1	0.65	0.48	0	0
F.Patent.Year$_{it}$	0.04	0.20	0	1	0.08	0.27	0	0
Patent.Year$_{it}$	0.22	0.41	0	1	0.40	0.49	0	0
Patent.Num$_{it}$	0.48	1.27	0	19	0.88	1.61	0	0
Patent.C.Year$_{it}$	0.83	1.591	0	9	1.51	1.894	0	0
Patent.C.Num$_{it}$	1.68	4.17	0	50	3.05	5.24	0	0
Publishing								
Paper.Num$_{it}$	2.15	2.93	0	30	2.74	3.37	1.42	2.05
Paper.JIF.Num$_{it}$	5.19	9.65	0	115.97	6.78	11.57	3.24	6.07
Paper.Applied.Num$_{it}$	0.82	1.50	0	13	1.09	1.62	0.48	1.14
Paper.Basic.Num$_{it}$	1.27	2.36	0	21	1.58	2.76	0.9	1.68