A Study of the Comprehensive Effects of a Top-Down Policy on UIRs: A Perspective of Principal-Agent Model

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Abstract--**Seemingly inspired by U.S. Bayh-Dole Act, many economics in distinctive contexts have been, if by agreed prior, promoting similar technology- or/and UIR-related legislation (university-industry relationships, UIRs), as a means of top-down policy aimed at commercializing result of academic research. Simultaneously, there are considerable studies paid attentions on the effect of technology legislation and probably got some findings out of the blue. However, very rare exploration was made to raise comprehensive understanding of the top-down mechanism in UIRs rationale. Based on Principal-Agent theory, this study attempts to develop a pattern to articulate why and how the effects of top-down policy on activities in UIRs vary with distinctive principal-agent relationship in stakeholders among UIRs. This paper compares main UIRs activities prior and post the introduction of Bayh-Dole-like act in Taiwan, one of major NIEs (new industrialized economies) in Asia, empirical evidences seemingly echo with the inferred model. These findings have profound implications for policy makers and researchers who are interested at exploring the strategies encouraging technology transfer of academic research.**

I. INTRODUCTION

Expanding the collaboration from World War II, American governments and universities collaborated hand in hand with problem-solving oriented research projects. With a purpose in facilitating exploitation of intellectual property rights (IPRs) resulted from academic research funded by governments, U.S. Congress enacted Bayh-Dole Act 1980 where the IPRs of federal-funded research could be granted to universities, public research institute and small firms. Followed with enactment of Bayh-Dole Act 1980, huge increases in number of patents granted to universities and royalty income had been found [4].

Seemingly inspired in the achievement of Bayh-Dole Act 1980, a number of economies (e.g. France, Japan, German, Brazil, Canada, Sweden) made a top-down policy with granting universities the IPRs resulted from government-funded research. Simultaneously, academic researchers and policy makers over the world paid attentions on effects of Bayh-Dole-like act and uncovered some unexpected findings. Reference [23] argue that followed the enactment of the Japan Bayh-Dole-like act 1990, numerous R&D activities in university-industry relationships (UIRs) had been promoted in the late of 1990s. Subsequently, remaining a similar or better quality, there are big increases in the number of patents developed in campus or UIRs after this legislative reforms. In German, a legislative action was taken in 2002 with a university reform in which the researcher and institutions are allowed the ownership of IPRs of results of government-funded research [30]. In contrast with fruitful achievements at patenting, [10] characterize and evaluate the S&T policy pursued in Sweden and US, both put a great deal of resources to support academic R&D, but followed very different models for commercialization. The Sweden infrastructure in terms of educational and social system might not provide adequate incentives for university to interact with industries; thus, the structural factors in Swedish academic environments possibly discourage academics from actively participating in the commercialization of their idea. Notwithstanding a numerous economics have promoted institutional reform of UIRs with top-down policies such as Bayh-Dole-like act, there are rare empirical evidences found in academic studies demonstrating that those top-down policies have had impact on raising technology innovation at country level. Reference [22] argued that lack of sufficient attentions on the underlying structural differences among the higher education systems and national innovation system, the other countries' legislative reforms emulating the U.S. Bayh-Dole Act will have modest success at best. The education ecology and UIRs situation in Taiwan, one of most important NIEs in Asia or over the world, are very distinct form America's. In contrast to long-lasting convention of academic entrepreneurships, almost all universities were founded after 1960 and were characterized as instruction emphasized institutions. On the other hand publish-based assessment mechanism adopted in Taiwan education authorities has critical impact on promotion of faculty and competition of resource for research projects. The discussions above explain that even Taiwan's universities had not routinely established UIRs as America's universities have did at the period prior passage of Bayh-Dole Act.

The purpose of this study is to explore changes in UIRs activities in all directions resulted from a legislative reform promoted in context of NIEs where universities may tend to be evoked to participate activities of technology transfer with remarkable institutional advantages both in providing a solution to the knowledge trade-off and in reducing agency costs [1, 28, 30]. Especially, we are wondering whether the enactment of Dole-Bayh-like act in NIEs would promote academic research becoming more applied. To address the issues already outlines and to begin to fill the gaps in the previous research, the present study is designed to address the following research questions: 1. Does an institutional reform introduced by government of NIEs lead to substantive and distinctive changes in UIRs activities? 2. What characteristics of theories could underlie the constructs explained the distinct

changes, if exist, caused by a legislative reform? The remainder of this paper is organized as follows. Section II presents historical overview of top-down policies to facilitate university-industry partnerships in U.S. and elsewhere. The following section identifies the effects of top-down policies on main stages of UIRs and develops a model explaining what we observed. In section IV we test several hypotheses of the model with secondary data. Section V includes and discusses the implications for future research.

II. BAYH DOLE ACT: RETROSPECT AND EMULATION

A. The American experience

Amongst findings in a lot of academic and practical articles focused at effect of Bayh-Dole Act it seems to be apparently that without reducing commitment to basic research, American universities have increasingly made endeavors on application research, commercialization and transfer of technology, patenting, licensing, academic entrepreneurship [20, 31, 36]. For instance, the number of patents issued to U.S. universities more than doubled between 1979 and 1984, more than doubled again between 1984 and 1989, and more than doubled again over the 1990s. Over this same period, university licensing revenues have virtually increased greatly as an increase in the number of patents issued to U.S. universities [24, 4].

B. A wave sweeping the world

Inspired by the results of U.S. Bayh-Dole Act, many countries in distinctive environments were promoting, if by agreed prior, a similar technology- or/and UIR-related legislation that is aimed at commercializing result of academic research [11, 22]. For instance, in Denmark, a 1999 law grants public research organizations, including universities, the rights to all inventions funded by the Ministry for Research and Technology. In France, a 1999 law permitted universities and public research organizations establishing policies to assert their rights to employee inventions. In Japan, a 1999 law shifted the ownership of fruits of academic research from individual inventors to universities [22, 25].

In contrast to heavy efforts, such as legislative reforms and financial supports, made by governments over the world outside U.S., there seem not to be adequate results of UIRs appeared, especially, on the latter stage of academic entrepreneurship. Reference [10] characterize and evaluate the S&T policy pursued in Sweden and US, both put a great deal of resources to support academic R&D, but follow very different models for commercialization. There is no strong incentive for HEIs to interact with industries; thus, the structural factors in Swedish academic environments possibly discourage academics from actively participating in the commercialization of their idea. Reference [22] argued that lack of sufficient attentions to the underlying structural differences among the higher education systems, the other countries' legislative reforms emulating the U.S. Bayh-Dole Act will have modest success at best. Continuing the line of argument developed earlier, a concept possibly peered that a variety of supports or changes/reforms will be needed in order to overcome distinctive resistances originated from activities in technology transfer. However, those articles seem not to put equivalent attentions to shed light on the extent to which top-down UIRs mechanisms can promote academic scientists engaging commercialization and transfer of technology.

C. Taiwan's Action: Fundamental Science and Technology Act 1999

Taiwan, one of most viable Newly Industrialized Economies (NIEs) in Asia, successfully entered high-tech age from 1980s and experienced fast economic growth for over two decades. Unsurprisingly, it faces the challenge of another round of upgrading because the development of the global high-tech industry soar a new height since the late 1990s [6]. Therefore some top-down policies and legislative reforms including Fundamental Science and Technology Act of 1999 (FST Act) are enacted by Taiwan Government to facilitate interactions between public research institute and industries from the last decade of late century. According to provisions of FST Act, a few approaches had been promised devoting to supporting the development and commercialization of academic R&D such as (a). increasingly raise public funded R&D expenditure (b). allow the universities or research institutions wholly or partially getting the ownership of intellectual property (IP) emanated from governmental funding R&D program (c). moderate autonomies are granted to universities, research institution and academics with latitude in dealing with purchase procedure, using technology as investment capital, allowing academic researcher holding other positions concurrently.

At the same time, a long-term restriction on foundation of university is deregulated by authorities and the number of universities swiftly increases from 50 to 145 in 10 years (see Table 2). Furthermore an evaluation system for higher education which focused on faculty's academic publication is promoted into Taiwan academia. Based on competition between scholars there seems to be incentives that attract academic scientists in traditional works, while technological initiatives including FST Act encourage them involving take innovative roles in UIRs.

III. CONCEPTUAL FRAMEWORK

A. Stages and key players in the process of UIRs .

Amid the compound process of technology transfer, there are a few of stages from ideas generation in the brain of academic scientists to the end use of academic technology. Reference [32, 33] generalized an idea of 7-stages in process of UIRs from the theory (see Fig. 1.) and 3 stakeholders were identified as key players in process of UIRs: (1) academic scientists, who conduct academic R&D and discover new technologies regarding activities in upstream of UIRs, (2)

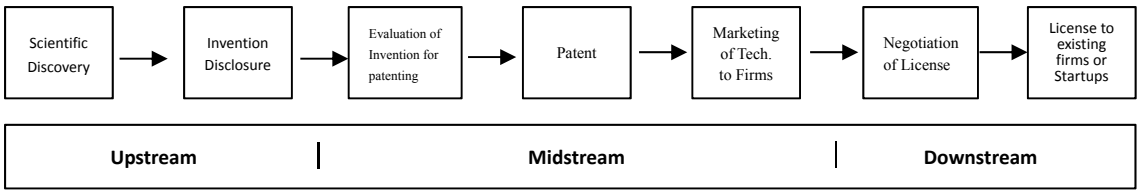

Fig. 1. Activities and stages towards UIRs
(Based on [31])

university technology managers and administrators, who serve as liaisons between academic scientists and industry and manage the university's intellectual property regarding activities in the midstream of UIRs , and (3) firms/entrepreneurs, who commercialize academic technologies regarding activities in downstream of UIRs. Though key stakeholders constituting an iron triangle underlay UIRs, however the traits and strength with regard to goals facing the key stakeholders vary with activities in stages of UIRs.

B. Exploring the influence of top-down policies with a lens of principal-agent framework

Considering Bayh-Dole Act's effect, there are a number of literatures that attempt to interpret interactions between key stakeholders of UIRs from the perspective of (multiple) principal-agent theory, with an individual level of analysis [1, 29, 30]. For instance, academic scientists involved in higher education institutions mainly purpose to further academic research rather than embody and maximize its commercial revenue [9, 18], on the other hand, the most important purpose for TTO managers and entrepreneur seek to exploit academic research to facilitate interest caught and business growth [29, 32]. Considering each stage in UIRs with its special mission and goal which attract and require different well-trained stakeholders working under organizations with absolutely distinct culture, it appears that a top-down policy with a single or little incentives or supportive mechanism might not be insufficient to provoke or reward all stakeholders engaging UIRs at their place. Early from the last two decades of last century, a top-down policy focused on IPR-granted and financial support had been deemed an effective and efficient measure to encourage universities and academics commercializing results of academic research. Followed up the enactment of U.S. Bayh-Dole Act 1980, a means of technology legislation has increasingly been emulated by major economics over the world. Simultaneously, there are considerable studies paid attentions on the effect of technology legislation and seemingly found some results out of the blue.

1) The comparison of impacts of top-down policy: upstream and midstream

In the upstream of UIRs, university R&D, academic researchers receive funds mainly supported by government departments (e.g. Department of Defense, DoD; Food and Drug Administration, FDA) who own specialized function and mission to conduct research program [17]. The relation between funding agencies and researchers can be conceptualized as a multiple principal-agent model [13, 37]. Based on the rationale of multiple principal-agent theory, there possibly are two problems need to deal with. First, academic scientists, the agent of public funded projects, would receive multiple pay-offs as their multiple identities (i.e. faculty, scientist, inventor and project executor). If the relative pay-off or reward is favored for one of the activities, there will probably be an incentive that the agent fulfills or tends to one side. For instance, the primary merit in university is publication in renowned journals, which provides strong incentives for academic scientists to focus on research only or be far away from non-publish-based tasks [30]. Secondly, academic R&D generally prefers to pursue tacit and advanced knowledge that may deteriorate the principal-agent risk in the process of scientific discovery [5, 13]. For instance, there is a possibility that academic scientists may deceive the funding agencies and use the funds to implement their own intended research or conceal key findings of funded research from principals [13, 12].

In contrast of academic scientists, managers of technology transfer office (TTO) as the key players in the midstream in UIRs paired with university in principal-agent relationship mainly acting on behalf of HEIs to look forward to opportunities for commercializing or maximizing academic research emanating from their employees. The knowledge and experience TTOs and managers learned as well as resources make them more efficient and adept at transferring scientific inventions, which are developed by scientists induced with scientific and academic norms, to technological innovations that are ready for commercial application [35, 14]. Therefore, it is perhaps much more profit for academic scientists to delegate their inventions to TTOs for commercializing rather than to engage in enormous business world themselves [16, 35]. A small number of scholars consider academic scientist as principal, managers in TTO as its counterpart [16]. Partly in line with [16], it is likely not to be precisely correct to characterize the inventor-TTO relationship as a principal-agent one in which the TTO is an agent of the academic inventor. First, without a contractual authority, academic scientists seem not to hold closely impacts on managers of TTO as principals do. Secondly, under the coherent command chain and administrative structure, managers of TTO can request administrators of

institute to arbitrate the serious controversy between academic scientists and managers, if it exists. For instance, after an invention disclosure filed by academic scientists, there may be a controversy between TTO and inventors with regard to whether the invention should be patented or not. In consultation with a committee of faculty experts and central administrators, TTO could make an objective decision which is not necessarily to meet inventors' expectation. These mechanisms within organization in which influence of academic scientists would be alleviated could substantively remedy principal-agent problem faced TTO [34].

Following previous discussion a hypothesis could be advanced with regard to the effect of top-down policy on upstream and midstream in UIRs:

Hypothesis 1a: The impact of a top-down UIRs policy would be more powerful at midstream rather than at upstream.

2) The comparison of impacts of top-down policy: midstream and downstream

Dominating over the downstream in UIRs, entrepreneurs supervise a firm (spin-off) acting on behalf of principal, board (venture capital), with the mission not only marketing innovation but also creating a market innovatively. Due to academic invention characterized novelty, it is likely that the potential valuation and utility of academic inventions may be hedged with the tacit and non-obvious nature. Therefore Firms typically cannot precisely assess the quality of the invention ex ante, while university/inventor may find it difficult to appraise the commercial profitability of their inventions [7]. Those problems of asymmetric information principally underlie the principal-agent conflict in the downstream of UIRs between university, Board and entrepreneur, scientists [3, 30]. Combining the discussion in prior section, a hypothesis could be advanced with regard to the effect of top-down policy on downstream and midstream in UIRs:

Hypothesis 1b: The impact of a top-down UIRs policy would be more powerful at midstream rather than at downstream.

3) The comparison of impacts of top-down policy: upstream and downstream

To principal-agent problem one standard solution is to better inform principal the actions of agent, i.e. to improve monitoring [29]. Within a number of prior studies, some "prescriptions" in the treatment of problem of asymmetric information have been proven to be effective. For instance, based on a prosper scheme specifying an adequate share of revenue in commercialization, academic scientists might be attracted to involve in activities in downstream of UIRs as a role of consultant, R&D researcher, problem-solving scientist, member in administrative tram or board [8, 15, 18]. In contrast to pecuniary incentives, some of institutional supports have been demonstrated to be effective or required via prior studies in promoting academics to branch out into activities of in-deep commercialization. A vast majority of them explicitly or implicitly give credits to that an extension of incentive structure encompassing promotion and tenure policies in which the leaves of absence or even freezing the tenure clock would be permitted for encouraging academics involved in activities of UIRs downstream such as being a consultant or member of board in a spin-off [11, 27, 33, 34, 36]. Therefore, the mechanisms discussed above can assist principal of UIRs downstream understanding and monitoring the performance of agents; nevertheless, the principals of UIRs upstream seem not to get an equivalent support in place. Based on the development form theoretical inferences, a hypothesis could be advanced with regard to the effect of top-down policy on upstream and downstream in UIRs:

Hypothesis 2a: The impact of a top-down UIRs policy would be more powerful at downstream rather than at upstream.

4) The comparison of impacts of top-down policy on activities of UIRs

Through a penetrating analysis discussed in the above section, this study attempt to propose a theoretical construct on which a more complete understanding of impact of top-down UIRs policy could be expected. The interactions and principal-agent problems between key players in stages of UIRs have been generalized in Table 1.

TABLE 1. KEY PLAYERS AND INTERACTION IN UIRS

Players Interaction / Stage in UIRs	Principals	Key Agents	Conflicts between Agents	Degree of asymmetric information	Strength over Multiple Principal-agent Problem
Upstream	Government/ HEIs/Firms	Academic scientists	Strong	Strong	Strong
Midstream	HEIs	TTO Managers/ Academic scientists	Moderate	Weak	Weak
Downstream	Firm Board /HEIs	Entrepreneur/ scientists	Weak	Strong/ moderate	Moderate/ Weak

(according to theory).

Based on that, a hypothesis could be advanced with regard to the effect of top-down UIRs policy:

Hypothesis 2b: The impact of a top-down UIRs policy on up- and downstream would be counted as "modest" in contrast to one on midstream.

IV. METHOD, DATA AND RESULTS

A. Research Data

This study takes a quantitative method to test hypotheses developed from research questions and inferences with high credible secondary data. The object of study, operation variables and analytical results will be subsequently elaborated.

The research data mainly derive from governmental or official agents such as National Science Council (NSC) and Ministry of Education (MOE) Taiwan, United States Patent and Trademark Office (USPTO), United States International Trade Commission (USITC), Organization for Economic Co-operation and Development (OECD) Library. Among all of them, the technology yearbook of Taiwan: "Indicators of Science and Technology" which have been issued by NSC over 2 decades is the key source of data.

B. Research Variables

First, we measured the activities in the upstream of UIRs with published in well-reputation journals cited in Science Citation Index (SCI). The annual number of papers published by Taiwan's scholars and citation ranking over the world separately represent the efforts on quantity and quality pertaining to activities of upstream of Secondly, Taiwan's UIRs. U.S. does be one of the global most important markets and one of the top 3 trade partner to Taiwan in which exports is the lifeline. Therefore Taiwan universities would tend to apply US patents with their superior-quality inventions aimed at seizing business opportunities on an early layout. On the other hand, the expenditure for application and maintenance of U.S. patents definitely cost Taiwan universities higher than local patenting. As discussion above, it is very likely that U.S. patenting would be one of activities representing result of UIRs midstream in Taiwan. Therefore it is very likely that the annual number of U.S. patents issued to Taiwan's university is a good symbol of midstream of UIRs. Finally, as discussed above on section 3.3.1 and 3.3.4, licensing the academic research may be the most important activity in the downstream of UIRs so that the annual licensing revenue would be one of the best indexes for the level of downstream of Taiwan's UIRs. Followed the explanation of variables, a number of data related activities in stages of UIRs have been collected and categorized as Table 2. Reflecting original data situation, there are lacks of completeness over two sets of data, number of faculty promoted with technology-based 1998 and prior, annual HEIs licensing revenue 2000 and prior. Since those activities just starting up at that time, the outcomes might be supposed to be tiny based on outcomes post the data-lacking period.

TABLE 2. DEVELOPMENT OF UNIVERSITIES IN TAIWAN BETWEEN PRE- AND POST-FST

	Annual published SCI papers	Taiwan's SCI Rank	Num. of faculty promoted with tech-based.	Num. of US uti. pat. granted to University in Taiwan	Num. of univ. & colleague	University licensing revenue m USD	University R&D Expenditure m USD
1991	3644	25	N/A	0	50	N/A	472
1992	4841	23	N/A	1	50	N/A	544
1993	5336	22	N/A	0	50	N/A	567
1994	6517	20	N/A	0	51	N/A	654
1995	7448	19	N/A	1	58	N/A	661
1996	8387	18	N/A	2	60	N/A	639
1997	8672	19	N/A	0	67	N/A	639
1998	9513	19	N/A	0	78	N/A	637
1999	9967	19	8	0	84	N/A	692
2000	10227	19	9	0	105	N/A	770
2001	10635	17	12	1	135	1.12	755
2002	10831	18	16	6	139	1.88	799
2003	12392	18	16	19	142	2.96	839
2004	12939	18	20	47	145	4.02	908
2005	15661	18	26	91	145	5.57	998
2006	17949	17	28	132	147	6.8	1155
2007	18795	16	20	171	149	9.27	1230
2008	22756	16	21	278	147	15.2	1361
2009	24521	16	28	372	147	15.8	1417
2010	23829	16	39	598	149	22.53	1516

Source: 1. Bureau of Statistics at Ministry of Education Taiwan, R.O.C.
2. Higher Education Evaluation and Accreditation Council of Taiwan
3. Patent Data Base at United States Patent and Trademark Office
4. Indicators of Science and Technology 2012; 2010; 1998; 1995; 1990 National Science Council Taiwan, R.O.C.

TABLE 3. THE COMPARISON OF OUTCOME OF TAIWAN'S ACADEMIC UIRS BETWEEN PRE- AND POST-FST

Activities / Period	Upstream		Midstream	Downstream
	Average annual publish papers in SCI	Taiwan's average SCI Ranking	Num. of US utility pat. granted to Taiwan's university	Average annual licensing revenue m USD
Pre-FST	7455	20.3	4	1.12
Post-FST	17030	17	1715	8.52

C. Analytical Results

As Table 3 illustrated, the ratio of total US utility patents granted to Taiwan' s in post-FST to one in pre-FST, 428.75 is larger than 2.28, the ratio of average annual publish papers in post-FST to one in pre-FST. In addition to an increase in number of papers published in SCI, another indicator that the global rank of Taiwan SCI publish-based outcome advanced from 20.3 to 17. According the data in existing document and clues, as we can find, there were very rare activities of UIRs downstream in prior 2000. The average annual licensing revenue increase from 1.12 million USD(FY 2001) to 8.52 million USD(FY 2010). The average annual published papers in SCI increased from 7455 of pre-FST to 17030 of post-FST and the SCI ranking declined from 20.3 to 17.

Furthermore, we use the Poisson Regression, a generalized linear model, to test the research hypotheses mentioned above. Table 2 reports the result of poison regression analysis. Hypothesis 1a, 1b, 2a are supported, while hypothesis 2b is partly supported.

V. DISCUSSION AND CONCLUSION

In this paper, we have considered the possible effects, at distinctive stages of UIRs or technology transfer, that a top-down technology legislation made which could partly be explained with principal-agent model. In considering this possibility we have gone beyond the typical concern about outcomes of UIRs or academic entrepreneurships mere focused on partial activities of that. We examine and compare the extent to which academic research and technology transfer have been practice with a perceptive of principal-agent mechanism. We find that the impact of FST Act is not significant on quality and quantity of SSCI, while significant on number of academic-US utility patent. On the other hand, the interaction of GROUP (pre- and post-FST) and Year has significant impact on revenue of university license, but didn't the "Year". The possible reason might be a lack of license data in 1990s. To some extent the present findings are in line with previous studies on assessing impact of legislative reform at individual activity of UIRs [20, 21, 22, 26, 35].

The present findings might contribute to the field's understanding of various changes in UIRs activities caused by an institutional reform. Previous researches argue that it is expedient to encourage academic scientists participating entrepreneurial project such as developing end-use products or spin-offs. Furthermore, we suggest that based on government-centered educational system in some NIEs as Taiwan, policy makers could make a consideration of integrating multiple incentives for UIRs activities into Bayh-Dole-like act or another institution reforms. Aimed at encouraging academics involved in technology transfer and UIRs earlier at academic career, it might be a feasible way to include performance and participation in commercialization of academic research as a determinant of promotion system for faculty.

Despite the long-term observations of multiple activities about UIRs, the design of the present study is not without limitations. There are some changes of endogenous factors in Taiwan's high education system such as a swift increase of universities and introduction of publish-based promotion mechanism parallel to the enactment of FST Act that probably limit research result and interpretations. While this study has its limitations, it is hoped that it can serve as a basis for future research in which the understanding about impact of institutional reforms could be more comprehensive.

TABLE 4. RESULTS OF REGRESSION ANALYSIS FOR OUTCOME OF TAIWAN'S ACADEMIC UIRS

Dependent Variable	Number of SSCI	Rank of SSCI	Number of academic-US utility patent	Revenue of university license
	Model 1	Model 2	Model 3	Model 4
Intercept	194.823***	63.271	83.039	-70.871***
Year	0.102***	-0.030	-0.92	0.039***
[Group=1]	-3.441	-31.830	-1059.596**	-89.266***
[Group=0]	0^a	0^a	0^a	0^a
[Group=1]*Year	0.02	0.16	0.531**	0.045***
[Group=0]*Year	0^a	0^a	0^a	0^a
Log Likelihood	-624.583	-48.084	-62.241	-101.386
Omnibus Test	59419.062***	4.733*	4175.644***	1991.076**

Model: (Intercept), Year, Group, Year*Group

a. Set to zero because this parameter is redundant

b. Group=1, post-FST (2001-2010); Group=0, pre-FST (1991-2000)

c. * P < 0.05, ** P < 0.01, *** P < 0.001

ACKNOWLEDGEMENTS

The authors acknowledge the valuable input by Shao-Chi Chun in searching patents of Taiwan's University issued from U.S. PTO.

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