INNOVATION CULTURE AMONG ACADEMICIANS IN BIOTECHNOLOGY R&D IN MALAYSIAN RESEARCH UNIVERSITY

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Abstract

How to get universities to better contribute to the innovation process has become an important issue in the evolution of the roles of institutions of higher education. This study sought to identify perceptions of academic researchers involved in biotechnology related research with regard to their commercialization activities of their researches by using a survey questionnaire. Based on the survey data, factor analysis was conducted to group commercialization activities variables into descriptive components. Subsequently, Kruskal Wallis tests were further carried out to differentiate the commercialization activities based on the demographic background. From the survey, it is apparent that most academic researchers perceived their commercialization activities are geared towards publication activities. Based on the factor analysis, commercialization activities of biotechnology related researches were found to consist of three groups; committee and network building (CNB), technology transfer (TT) and intellectual property and academic writing (IPAW). Findings of Kruskal Wallis tests showed that demographic background affects academic researchers who were involved in commercialization activities of biotechnology related researches.

Keywords: Biotechnology R&D, Innovation Culture, University

Introduction

The changing nature of the university's role makes commercialization of university research results more relevant nowadays. Faced with budgetary difficulties, universities now attempt to actively market their discoveries to industry, use their inventions to form new companies and engage in commercial activity related to economic development. These initiatives are described by Slaughter and Leslie (1997) as marking a new era of academic capitalism leading to what Etzkowitz (1983) terms as entrepreneurial universities.

Nelson (2001) contrasts these new initiatives with older norms favoring the open dissemination of research discoveries. Previously, scientists working in university laboratories were, in general, content to pursue their investigations without giving much thought to the practical application of the result. The discovery and development of patentable inventions was not the primary objective of their research efforts. Today, we are witnessing a distinct departure from tradition, where many academic scientists avoided patenting and involvement with industry (Feldman and Desrochers, 2004) and choose to focus on teaching and research. Nevertheless, the changing role of universities from knowledge production to capitalization of knowledge, with the objective of improving regional or national economic performance as well as the university's financial advantage, (Etzkowitz *et al.*, 2000) has led to an increase in the commercial activities among universities in the last two decades.

This evolution of the roles of the universities in developed countries also imposed new demands and pressures on the developing countries' higher education system (Altbach and Ogawa, 2002; Teichler, 2003). Within this context, in developing countries, research universities are seen as vehicles for technology transfer and a medium through which knowledge exchange is made more effective. This highlights the importance of promoting commercialization activities of research results

among academic researchers. This is because the individual academic researcher is central to the knowledge and technology transfer process in making strategic decisions about how to disseminate their research results in the university. Researchers decide whether or not to collaborate with industry, disclose their inventions to their university and/or start a company based on his/her knowledge. An increase in activity at the level of the individual academic will also accompany the shift from policy to implementation. The academic researchers' involvement needs to go well beyond simply disclosing their research results to Technology Transfer Office; they must also identify licensees as well as work with licensees in further development (Thursby and Thursby, 2004).

Interestingly, there are limited studies on the commercialization activities of research results, particularly at Malaysian research universities that focus on the academic researcher. With the realization that academic researchers are viewed as critical to the process, questions as to what types of commercial research activities are apparent among academic researchers in Malaysian research universities is still open for research. Further, D'Este and Patel (2007), show that the characteristics of individual researchers have a stronger impact than the characteristics of their departments or universities on the variety and frequency of interactions with industry. This finding highlights the need to look further at differences in commercialization activities based on demographic information.

Commercialization Activities of Research Result

There is a misconception about the difference among research, knowledge and technology. Gray and Walters (1998: 219) provided this clarification: 'The important point is that technology implies the application of knowledge having practical value and utility. Research results are not the same thing as a technology. Research results whether empirical findings, statistical relationships, or new conceptual schema, are new knowledge'.

Definitions of knowledge are related to epistemological perspective: positivists view knowledge as an object whereas constructivists view knowledge as a process (Polanyi, 1996; Sveiby, 1997). When knowledge is viewed as an object, it becomes an artifact, a static, formal and perishable commodity whose value changes and erodes over time. When viewed as a process, knowledge is organic, fluid, dynamic and in a constant state of flux and evolution. The means of knowledge involve social interaction, answering questions or engaging in problem solving (Handy, 1989). In the context of this study, the concept of research result is defined using the constructivist paradigm.

Noticeably, most of the research to date has focused on the technology, at the time it leaves the university, either through licensing to commercial firms or the creation of start-ups. Most common indicators, like patent activity, licensing activity, license income and start-up companies formed, tend to have a narrow focus on commercial activities. This narrow focus fails to capture the different ways universities provide commercial benefits to industry. Less attention has been focused on the other activities that occur before the technology leaves the university setting. In order to have a better understanding of the commercialization among academic researchers in Malaysian research universities, other activities, that occur before the technology leaves the university setting, is needed to look at. Thus, the scope of commercialization used in this study are more comprehensive, not limited to technology transfer activities such as patenting, licensing and spin off, but initial efforts that contribute to the commercialization are also taken into account, including knowledge transfer activities that have value and commercial motives.

Why Biotechnology Related Research?

Biotechnology, which is composed of a group of technologies based on molecular biology, enables scientists to genetically manipulate and replicate living cells. Biotechnology delivers a host of applications to areas such as medicine, agriculture, food processing and energy (Argyres and

Liebeskind, 1997). Distinct from other high technologies, biotechnology is a science based activity and its development primarily derives from academic research. The biotechnology research and development cycle often starts with some basic research designed to provide a better understanding of the biochemistry of the issue at the molecular level, forming a basis for new product concepts.

Cohen and Noll (1994) argued that biotechnology commercialization offered universities the promise of significant increases in income at a time when Federal and other grants were increasingly constrained and public support for Federal research funding was declining as basic research in this area often has immediate and significant commercial value. In addition, biotechnology was also reported by firms to be the area of university scientific research most relevant to their operation (Levin *et al.*, 1987). Orsengio (1989) described biotechnology scientists who conduct basic research as the most likely to discover the new substances that constitute patentable, commercially valuable inventions. These findings further highlight the importance of the biotechnology research field.

However, the characteristics and the range of issues relevant to the commercialization of biotechnology research may be different in developing countries than those in industrialized countries. In industrialized countries, biotechnology is viewed as an all-pervasive profit-generating technology and a strategic component of industrial competitiveness. However, in the context of developing countries in general, and Malaysia in particular, the translation of this science base into commercial business is, relatively, at the emergent stage.

Previous reports and studies appear to be predominantly based on the experiences of universities in developed and industrialized economies, particularly the United States, the UK and other Organization for Economic Co-operation and Development (OECD) countries where commercialization activities are more prevalent. Even though universities are the largest source of such academic capital, transforming this raw resource into successful market bioscience products and treatments is a complex process with a low success rate (Jarret, 2007). Association of Technology Managers report (AUTM, 2006) states that the actual return on investment that universities received for their support of technology transfer in fiscal year 2004 was only 15 cents on the dollar. The number of institutions reporting annual royalties of more than $20 million also decreased from 14 institutions in 2000 to 11 in 2001. In contrast, the number of inventions and patent filings increased during the same reporting period, showing the positive participation from academicians. The number of inventions rose from 10,802 in 2000 to 11, 259 in 2001 and 16,871 in 2004. Patent filings also increased by approximately 1,000 between fiscal year 2001 and fiscal year 2000 and have continued to increase each fiscal year since (AUTM, 2006). Another survey report (Feldman *et al.*, 2002) also describes the small success rate related to discoveries, citing that of all invention disclosures; only a small number resulted in interest from potential licensees, with an even smaller number generating any license income. Although there has been some success in the transfer of university biotechnology research to industry, the rate is not convincing enough, even in developed countries.

In Malaysia specifically, in the Ninth Malaysia Plan (2006-2010), biotechnology is a highly prioritized sector in Malaysia's national policy because the government has high hopes of achieving international excellence and academic and commercial success in this field. Therefore, it has received strong governmental support and commitment through financial support for its research and development, infrastructure and human resource development. Malaysian research universities with relatively good research and development track records could eventually contribute to the progress of biotechnology.

Sampling Frame for Survey

A list of academic researchers was obtained from the Malim Sarjana expertise database developed by the Higher Education Ministry. The list includes active academic researchers from the fields of molecular biology, plant biotechnology, animal biotechnology, industrial and environmental biotechnology, forensic biotechnology, food biotechnology, biopharmacy biotechnology, marine

biotechnology, bioinformatics and biosafety and bioethics. Altogether, four research universities and 209 academic researchers who are involved in biotechnology research related were identified as a potential population of the study.

According to Sekaran (2003:424), a stratified random sampling is a 'probability sampling design that first divides the population into meaningful, non-overlapping subsets, and then randomly chooses the subjects from each subset'. By using a simple random sampling scheme, samples are drawn from each stratum and then the selected observations are pooled to form a single sample set. Within the context of this study, each research university is treated as independent, thus making stratified sampling method appropriate for developing the final sampling frame for the survey.

Method

Data for the study was collected by a survey questionnaire designed to obtain biotechnology academic researchers' perception relating to commercialization. The questionnaire for the study consists of two sections: Commercialization activities of Research Result and Demographic Information. The first part is comprised of commercialization activities of research result which was adopted from Ahmad (2008) and modified by the author to suit the requirement of the study. There are 11 items of commercialization of research. Commercialization activities of research results include: (1) publishing academic writing, (2) communicated to other users outside the academic environment/priority parties such as private firms or government agencies through seminar, conference, exhibition, report in printed or electronic media, (3) presentation of research to groups and organizations who could make direct use of them, (4) been involved in committees which are interested in using and exploiting new knowledge based on the research result, (5) given consultation/technical service (based on technology field/research result) to private firms, government agencies or others, (6) disclosed the invention based on my research result, (7) applied for patents based on my research result, (8) obtained a patent based on my research results, (9) gave the license to other parties or organizations to produce or market the product from my research (10) the license that have been given to other parties, has resulted in monetary return and (11) research result has created spin off company(s) that specifically produce and commercialize the research product. The aforementioned 11 items are consistent with those identified by Landry, Amara, and Ouimet (2006).

The second part of the questionnaire is comprised of four types of demographic information including research experience, highest level of education, experience as administrator/top level management and academic post status. Towards the end, the respondents were requested to provide comments on their attitude to ensure that their personal views could be expressed without being restricted by the five-point scale.

Findings

Descriptive Analysis

Seventy nine academicians working on biotechnology related research in Malaysian research universities participated in the survey. The descriptive analysis of the collected data illustrated the diverse background of respondents even though they originated from four Malaysian research universities. With reference to Table 1, it is evident that most of the respondents have more than ten years research experience in the university (43%), followed by academicians with five to ten years' experience (35.4%) and with less than five years' experience (21.5%). As expected, the majority of the respondents (78.5%) possess a PhD. Masters and Post-doctoral holders place second and third place respectively. Regarding the experience as administer or top level management, the analysis revealed that most of the respondents (49.4%) had experience at faculty level, no experience (29.1%), university

level (15.2%) and research center level (6.3%). Finally, the highest percentage of the respondents was Associate Professor (29.1%), Senior Lecturer (25.3.3%), Professor (24.1%) and Lecturer (21.5%).

Table 1: Frequency Analysis on Demographic Background

RESEARCH EXPERIENCE	**Frequency**	**Percent**	**Cumulative Percent**
Less than 5 years	17	21.5	21.5
5 to 10 years	28	35.4	57.0
More than 10 years	34	43.0	100.00
Total	79	100.0	
EDUCATION LEVEL	**Frequency**	**Percent**	**Cumulative Percent**
Master	10	12.7	12.7
PhD	62	78.5	91.1
Post-doctoral	7	8.9	100.0
Total	79	100.0	
ADMINISTER /TOP LEVEL MANAGEMENT EXPERIENCE	**Frequency**	**Percent**	**Cumulative Percent**
Faculty	39	49.4	49.4
Research Centre	5	6.3	55.7
University	12	15.2	70.9
No experience	23	29.1	100.0
Total	79	100.0	
ACADEMIC POST	**Frequency**	**Percent**	**Cumulative Percent**
Lecturer	17	21.5	21.5
Senior Lecturer	20	25.3	46.8
Associate Professor	23	29.1	75.9
Professor	19	24.1	100.0
Total	79	100.0	

Factor Analysis

Within the context of this study, exploratory factor analysis was used to identify components produced by the factor analysis. For the eleven questionnaire items, there are 79 cases in the sample, which is sufficient enough for conducting a single factor analysis using Varimax Rotation method with Kaiser normalization and Principal Component Analysis. In the factor analysis, factors were extracted when the Eigen values are greater than one. The factors extracted have explained almost 70.96% of the total variance, meaning that they are satisfactory solutions.

Two statistical tests should be done in order to allow for the application of factor analysis, namely, Kaiser-Meyer-Olkin (KMO) sampling adequacy test and the Barlett's test of sphericity. The KMO sampling adequacy test statistic for this study is 0.847 which is higher than the threshold value of 0.5 (Hair *et al.,* 1998). This is supported by Barlett's test of sphericity value of 0.00 that is less than 0.05. These two tests seem to support the usage of the factor analysis method using Varimax rotation with Kaiser Normalization and Principal Component Analysis. Varimax with Kaiser Normalization was applied prior to factor rotation, thus keeping factors with an Eigen value of one and greater. Principal component analysis was the chosen extraction method to describe the data set with a smaller set of new variable.

The factor analysis extracted three factors based on eigen value criteria more than one. These three factors together accounted for 70.96% of the total variance. Within the context of this study, typology development has been used as analytical strategy where a quantitative survey was conducted, developed factors through a factor analysis and using this factors as a typology (Caracelli and Greene, 1993). Items of Commercialization Activities of Research Results are regrouped into different groups based on the extraction value of the rotated component matrix namely CNB, TT and IPAW as indicated in Table 2.

Table 2: Result of the Factor Analysis of Commercialization Activities of Research Results

Attributes	Description	Components		
		CNB	TT	IPAW
X_4	I have been involved in a committee which is interested in using and exploiting new knowledge based on the research results.	.818		
X_3	I have been invited to present to a group and organizations which could make direct use of my research results	.813		
X_5	I have given consultation/technical services (based on my area of specialization/research results) to private firms, government agencies and others.	.810		
X_2	Other than towards academicians, my research results have been communicated to other users outside the academic environment/priority parties such as private firms or government agencies through seminars, conferences, exhibitions and reports in the printed or electronic media.	.737		
X_6	I have disclosed the invention/innovation based on my research results.	.557		
X_{10}	The license granted to other parties has resulted in monetary returns to the university/me in the form of royalties, equities and profit sharing.		.850	
X_{11}	My research results have created spin off company(ies) that specifically produce and commercialize my research product.		.824	
X_9	The university/I have licenced to other parties or organizations to produce or market the products from my research.		.767	
X_8	I have obtained patent based on my research results.			.878
X_7	I have applied for patent based on my research results.			.850
X_1	My research results have been published in various forms of academic writing (example books and journals).			.512
	Eigen value	5.179	1.539	1.088
	Percentage of Variance Explained	47.077	13.987	9.895

The first group can be classified as committee and network building (CNB) and is comprised of five items from the Commercialization Activities of Research Results. The following are the items of CNB: *been involved in committee which is interested in using and exploiting new knowledge based on the research result, invited to present research results to group and organization who could make direct use of them, given consultation service/technical (based on technology field/research result) to private firm, government agency or others, communicated to other users outside the academic environment/priority parties such as private firms or government agencies through seminar, conference, exhibition, report in printed or electronic media* and *disclosed the invention based on my research result.*

The second group can be classified as technology transfer (TT) and comprises of three items from the commercialization activities of research results. The following are the items of TT: *the license that have been given to other party have been resulted in monetary return, research result has created spin off company that specifically produce and commercialize the research product* and *gave the licence to other party or organization to produce or market the product from my research.*

The final group of commercialization activities of research results can be classified as intellectual property and academic writing (IPAW). The items classified under this group are the following: *obtained patent based on research result, applied for patent based on my research result* and *publishing academic writing.*

Kruskal-Wallis Analysis

Because of the ordinal nature of frequency scale, Kruskal-Wallis test was used to test hypotheses on differences in mean ranking of eleven questionnaire items using five-point scales related to commercialization activity of research results based on demographic background of the respondents. The Kruskal-Wallis tests are applicable for all cases in this study, where all the demographic variables have more than two categories; research experience, highest level of education, experience as administrator/top level management and academic post status. Forty-four Kruskal-Wallis based hypotheses were formulated accordingly. As an example, for the first item, the null hypothesis would be: there is no difference in mean ranking of *My research results have been published in various forms of academic writing* based on research experience. The null hypotheses would be rejected if the p-values were found to be lower than 0.05 for all the Kruskal Wallis tests. For this study, p-values that are less than 0.05 will be highlighted.

The significant findings for the Kruskal Wallis and its relevant descriptive statistics are as follows:

1. There is difference in mean ranking of *My research results have been published in various forms of academic writing* based on research experience whereby the mean ranking of impact by those who have more than 10 years research experience is the highest (45.34) while mean ranking of impact by those who have less than 5 years research experience is the lowest (25.00).

2. There is difference in mean ranking of *Other than towards academicians, my research results have been communicated to other users outside the academic environment/priority parties such as private firms or government agencies through seminars, conferences, exhibitions and reports in the printed or electronic media* based on research experience whereby the mean ranking of impact by those who have more than 10 years research experience is the highest (46.41) while mean ranking of impact by those who have less than 5 years research experience is the lowest (26.03).

3. There is difference in mean ranking of *I have been invited to present to a group and organizations which could make direct use of my research results* based on research experience whereby the mean ranking of impact by those who have more than 10 years research experience is the highest (51.66) while mean ranking of impact by those who have less than 5 years research experience is the lowest (24.35).

4. There is difference in mean ranking of *I have been involved in a committee which is interested in using and exploiting new knowledges based on the research results* based on research experience whereby the mean ranking of impact by those who have more than 10 years research experience is the highest (45.19) while mean ranking of impact by those who have less than 5 years research experience is the lowest (28.21).

5. There is difference in mean ranking of *I have given consultation/technical services (based on my area of specialization/research results) to private firms, government agencies and others* based on research experience whereby the mean ranking of impact by those who have more than 10 years research experience is the highest (50.65) while mean ranking of impact by those who have less than 5 years research experience is the lowest (23.53).

6. There is difference in mean ranking of *I have disclosed the invention/innovation based on my research results* based on research experience whereby the mean ranking of impact by those who have more than 10 years research experience is the highest (46.82) while mean ranking of impact by those who have less than 5 years research experience is the lowest (32.12).

7. There is difference in mean ranking of *I have applied for patent based on my research results* based on research experience whereby the mean ranking of impact by those who have more than 10 years research experience is the highest (47.68) while mean ranking of impact by those who have less than 5 years research experience is the lowest (31.41).

8. There is difference in mean ranking of *I have obtained patent based on my research results* based on research experience whereby the mean ranking of impact by those who have more than 10 years research experience is the highest (47.32) while mean ranking of impact by those who have 5 to 10 years research experience is the lowest (38.32).
9. There is difference in mean ranking of *The university/I have licenced to other parties or organizations to produce or market the products from my research* based on research experience whereby the mean ranking of impact by those who have more than 10 years research experience is the highest (46.66) while mean ranking of impact by those who have 5 to 10 years research experience is the lowest (35.91).

10. There is difference in mean ranking of *The license granted to other parties has resulted in monetary returns to the university/me in the form of royalties, equities and profit sharing* based on research experience whereby the mean ranking of impact by those who have more than 10 years research experience is the highest (47.60) while mean ranking of impact by those who have less than 5 years research experience is the lowest (33.85).

11. There is difference in mean ranking of *My research results have created spin off company(ies) that specifically produce and commercialize my research product* based on research experience whereby the mean ranking of impact by those who have more than 10 years research experience is the highest (45.78) while mean ranking of impact by those who have less than 5 years research experience is the lowest (34.32).

12. There is difference in mean ranking of *I have disclosed the invention/innovation based on my research results* based on education level whereby the mean ranking of impact by post-doctoral holder is the highest (52.43) while mean ranking of impact by PhD holder is the lowest (36.75).

13. There is difference in mean ranking of *I have obtained patent based on my research results* based on education level whereby the mean ranking of impact by post-doctoral holder is the highest (54.57) while mean ranking of impact by PhD holder is the lowest (37.23).

14. There is difference in mean ranking of *The university/I have licenced to other parties or organizations to produce or market the products from my research* based on education level whereby the mean ranking of impact by post-doctoral holder is the highest (51.64) while mean ranking of impact by PhD holder is the lowest (37.05).

15. There is difference in mean ranking of My *research results have been published in various forms of academic writing* based on administration/top level management experience whereby the mean ranking of impact by those who have administration/top level management experience at university level is the highest (54.88) while mean ranking of impact by those who have no administration/top level management experience at all is the lowest (28.39).

16. There is difference in mean ranking of *Other than towards academicians, my research results have been communicated to other users outside the academic environment/priority parties such as private firms or government agencies through seminars, conferences, exhibitions and reports in the printed or electronic media* based on administration/top level management experience whereby the mean ranking of impact by those who have administration/top level management experience at university level is the highest (53.38) while mean ranking of impact by those who have no administration/top level management experience at all is the lowest (28.24).

17. There is difference in mean ranking of *I have been invited to present to a group and organizations which could make direct use of my research results* based on administration/top level management experience whereby the mean ranking of impact by those who have administration/top level management experience at university level is the highest (51.63) while mean ranking of impact by those who have no administration/top level management experience at all is the lowest (26.37).

18. There is difference in mean ranking of *I have disclosed the invention/innovation based on my research results* based on administration/top level management experience whereby the mean ranking of impact by those who have experience at university level is the highest (52.71) while mean ranking of impact by those who have no administration/top level management experience at all is the lowest (26.17).

19. There is difference in mean ranking of *I have applied for patent based on my research results* based on administration/top level management experience whereby the mean ranking of impact by those who have experience at university level is the highest (53.58) while mean ranking of impact by those who have no administration/top level management experience at all is the lowest (28.35).

20. There is difference in mean ranking of *I have obtained patent based on my research results* based on administration/top level management experience whereby the mean ranking of impact by those who have experience at university level is the highest (54.88) while mean ranking of impact by those who have who have no administration/top level management experience at all is the lowest (32.13).

21. There is difference in mean ranking of *The university/I have licenced to other parties or organizations to produce or market the products from my research* based on administration/top level management experience whereby the mean ranking of impact by those who have

experience at university level is the highest (53.04) while mean ranking of impact by those who have who have no administration/top level management experience at all is the lowest (30.46).

22. There is difference in mean ranking of *The license granted to other parties has resulted in monetary returns to the university/me in the form of royalties, equities and profit sharing* based on administration/top level management experience whereby the mean ranking of impact by those who have experience at university level is the highest (57.21) while mean ranking of impact by both those who have no administration/top level management experience at all and have administration/top level management experience at research centre level are the lowest (29.50).

23. There is difference in mean ranking of *My research results have created spin off company(ies) that specifically produce and commercialize my research product* based on administration/top level management experience whereby the mean ranking of impact by those who have experience at university level is the highest (47.92) while mean ranking of impact by those who have administration/top level management experience at research centre is the lowest (30.00).

24. There is difference in mean ranking of *My research results have been published in various forms of academic writing* based on academic post whereby the mean ranking of impact by those who work as professor is the highest (53.42) while mean ranking of impact by those who work as senior lecturer is the lowest (29.35).

25. There is difference in mean ranking of *I have been invited to present to a group and organizations which could make direct use of my research results* based on academic post whereby the mean ranking of impact by those who work as professor is the highest (55.05) while mean ranking of impact by those who work as lecturer is the lowest (27.85).

26. There is difference in mean ranking of *I have applied for patent based on my research results* based on academic post whereby the mean ranking of impact by those who work as professor is the highest (54.53) while mean ranking of impact by those who work as lecturer is the lowest (34.18).

27. There is difference in mean ranking of *I have obtained patent based on my research results* based on academic post whereby the mean ranking of impact by those who work as professor is the highest (51.47) while mean ranking of impact by those who work as associate professor is the lowest (35.30).

28. There is difference in mean ranking of *The university/I have licenced to other parties or organizations to produce or market the products from my research* based on academic post whereby the mean ranking of impact by those who work as professor is the highest (50.50) while mean ranking of impact by those who work as lecturer is the lowest (33.94).

29. There is difference in mean ranking of *The license granted to other parties has resulted in monetary returns to the university/me in the form of royalties, equities and profit sharing* based on academic post whereby the mean ranking of impact by those who work as professor is the highest (51.63) while mean ranking of impact by those who work as lecturer is the lowest (34.32).

30. There is difference in mean ranking of *My research results have created spin off company(ies) that specifically produce and commercialize my research product* based on academic post whereby the

mean ranking of impact by those who work as professor is the highest (49.71) while mean ranking of impact by those who work as senior lecturer is the lowest (35.70).

Conclusion

The study found that commercialization activities in Malaysian research universities are geared towards information dissemination. In fact, previous studies also showed that patents, licenses and spin offs form a relatively small part of knowledge transfer from universities (Cohen *et al.*, 2002; D'Este and Patel, 2007; Bekkers and Bodas Freitas, 2008). This result was consistent with Muscio and Geuna (2009) who found that most university knowledge is transferred via traditional channels such as personal exchanges, publishing, consulting and conferences. Estimates of relative importance of different knowledge channels suggest that these 'non-commercial' methods represent the majority of knowledge transferred from universities to industry (Agrawal and Henderson, 2002). In survey of Research and Development (R&D) managers across many industries, Cohen et al. (2002) also found that the most important channel for knowledge transfer from universities or government labs is publication of the research, followed by informal exchange, public meetings or conferences and consulting.

Furthermore the study uncovered three groups of commercialization activities of biotechnology related research among academic researchers in Malaysian research universities. The groups can be classified as committee and network building (CNB), technology transfer (TT) and intellectual property and academic writing (IPAW).

The study also found that commercialization activities of research result are affected by research experience, highest level of education, experience as administrator/top level management and academic post status. Overall, the study shows that out of the eleven commercialization activities of research results, only two commercialization activities are shown to have significance difference in mean ranking based on its p-value being less than 0.05 for all demographic backgrounds. This implies that there is a difference in mean ranking of *I have obtained a patent based on my research results* and *The university/I have licenced to other parties or organizations to produce or market the products from my research* based on research experience, highest level of education, experience as administrator/top level management and academic post status. The biggest impact for the three commercialization activities are from academic researchers who have more than 10 years' experience, post-doctoral holder, experience as administrator/top level management at university level and hold a title of professor.

It is interesting to note that research experience is shown to have a significantly different mean ranking based on its p-value being less than 0.05 for all eleven commercialization activities of research results with highest mean for the academic researchers who have more than 10 years' experience. However, highest level of education, experience as administrator/top level management, post-doctoral holder and academic post status have some effect on other commercialization activities of research results with the highest mean for the academic researchers who have a post-doctoral designation, experience as administrator/top level management at university level and hold the title of professor. This finding is also supported by previous work done by Allen *et al.*, (2007) that indicate faculty research productivity according to appointment type (tenure-track faculty were more research productive than were faculty on other appointments) and research productivity by rank (e.g., full professor, associate professor, and assistant professor) were significant predictors of faculty research productivity.

Limitation of the Study

The higher education systems in Malaysia during this study period consisted only of four research universities with limited autonomy and tightly controlled by the government. This has limited the ability of the academics to engage in collaborative activities with industries. For instance, academic staff employed by these universities were considered civil servants, subject to strict public service regulations imposed by the Malaysian Public Service Department, including restrictions not only on the number of working hours with industry but also on the amount of money that could be received from activities such as consultant fees. In effect, universities and their academic staff were not allowed to engage in commercial activities, including exploitation of academic research results. Commercialization of research results therefore was minimal during this study period as indicated by the findings of the survey of commercialization activities of research result among academic researchers.

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