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Analysing the Importance of Demographic Factor as Determinant of Research Efficiency through Data Envelopment Analysis

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Abstract: The current study aims to discuss the importance of how efficiently researchers utilize research grants from public grants, private institutions, and international agencies. This paper adopts the Data Envelopment Analysis (DEA) method to measure the relative inefficiencies of University Putra Malaysia (UPM) faculty members using data collected from 2010 to 2016. This research also investigates the relationships between demographic factors, the field of study, and research inefficiency. The input and output variables used in this study are research grants received by academic faculty members and their corresponding publications in Citation Indexed Journals (CIJ), non-CIJ, and publishing books and chapters in books, with each output, measured separately. Data is divided into two clusters: science and social science. The demographic factor examined is the academic position of the researcher. Research inefficiency for both science and social science fields generally worsens with higher academic positions. The effect for the science field is more pronounced for CIJ, non-CIJ, and books. This study will be adding new knowledge on the relationship between age and research productivity based on the Malaysian environment and culture. It also will be a guideline for policy formulation in public universities in managing talent pool based on age influence towards research productivity.

Keywords: Research efficiency, DEA, Public universities

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INTRODUCTION

Malaysian Research Universities (MRU) were established in 2006 and play a diverse role in the development of the nation including being an international hub of education, creating new industries at early stage, attracting and developing the best talents, as well as providing solutions to the community and industries. One of the core functions of MRU is to supply human resources for the expanding and changing economy with the aim that Malaysia will become a high income country by 2020. MRU were established as an educational policy based on the view that universities should breed intellectual capital, new knowledge and innovative technology, besides become the main engine in producing graduates for the workforce. The mission for the establishment of MRU is to be an engine of growth of the nation that provide spaces for scholars and students to exchange ideas, conduct research in a conducive environment that nurtures exploration and creativity to discover knowledge and create wealth, leading towards an improved quality of life (Ministry of Education Malaysia, 2014). The Malaysian higher education system has grown from strength to strength over the past few decades. Under the Ninth Malaysian Plan, RM18.4 billion has been disbursed by Malaysian Government to the Ministry of Higher Education as compared to RM13.2 billion under the previous development plan (Aziz, Janor, & Mahadi, 2013; Chan, 2018).

In the first five years of MRU (2007-2012), each RU received between RM50 to RM90.8 million per

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year as operational cost including for research, fellowship, training and equipment and enhancing facilities. On the whole, the total investment on the MRU is RM1.863 billion (Ministry of Education Malaysia, 2014; Lin, Lee, Wu, & Ho, 2018; Sylvia, Pidor, Limjuco, & Barluado, 2017). As of 2015, government expenditure on higher education had been rising at a rate of 14% per annum, comprising largely of subsidies to public Higher Learning Institutions (HLI) including MRUs, which a total of 90% of their expenditure is funded by government (Ministry of Higher Education Malaysia, 2016).

The Malaysia Education Blueprint 2015-2025 (Higher Education), or the MEB (HE) came about with the intention to transform HLIs and spur continued excellence in higher education. Financial stability is one of the ten shifts that the MEB (HE) relies on. MRUs are expected to seek diverse sources of funding as well as being prudent and innovative in the use of their resources. In 2014 and 2015, universities managed to obtain a total of RM1.35 billion, RM81 million and RM40 million from public grants, private agencies and international bodies respectively (Ministry of Higher Education Malaysia, 2016). In ensuring financial sustainability, it is not only important to ensure that the grants received are used effectively but efficiently as well. Gross inefficiency in utilising grants by universities would result in less grant funders for the future generations.

Universiti Putra Malaysia is one of the universities that have been awarded as MRU status. UPM started its journey in 1931 from a small agricultural school into what is today a leading learning and Research University which is well respected both nationally and internationally.

In 1947, the school was declared by Sir Edward Gent, the then Governor of the Malayan Union as the College of Agriculture Malaya. The formation of Universiti Pertanian Malaysia is a merged between College of Agriculture in Serdang and Faculty of Agriculture, University of Malaya. In 1997, the name Universiti Pertanian Malaysia was changed to Universiti Putra Malaysia by former Prime Minister, Tun Dr. Mahathir Mohammad. This can be seen as a strategic gesture to portray the status of UPM as a centre of higher education capable of providing various fields of studies, specifically in science and information technology, which facilitate national development in the new era (http://www.upm.edu.my/).

This paper is divided into five (5) sections: Section 1 will explains further on problem statement; section 2 gives a brief review of the relevant literature and specifically variables used as inputs and outputs in similar studies; section 3 gives a background on research design and Decision making Units (DMUs) used in this study; findings from this study are given in section 4 and the last section will concludes the paper.

PROBLEM STATEMENT

MRUs are tasked with scientific advancement and innovation. A researchers professional work is only considered as a contribution only after the research findings and results has been distributed to peers for feedback and validation. The primary mode of communication to achieve this is through the publication process, which allows the scientific community to verify the reliability of information, ascertain the relative importance of the contribution and give critical response to the work (Fox, 1983).

Therefore, a key performance indicator for MRU is research publications. Throughout the year, the number of research articles published by Malaysian universities increased more than threefold between 2007 and 2012, the highest increase in the world, and the number of citations grew fourfold from 2005 to 2012.

Professors play an important roles in Research Universities but the time needed to achieve the position of Professor would mean that benefits accorded to the University is constrained by the retirement age.

Furthermore, as university researchers gain recognition and are awarded with academic positions such as professor or associate professor, they would be additionally burdened with administrative duties. However, higher administrative positions would also result in access to resources that increase the possibility of publications (Fox, 1983; Huang, Chang, & Lin, 2016; Taorid, 2016). One of which is grants, therefore it is expected that publication productivity would increase with higher academic position.

The five MRU alone contributed 70% of these publications (Ministry of Education Malaysia, 2014). This is in sync with the fact that part of the criteria for the assessment of RU performance are “quantity

and quality of Researchers" and "quantity and Quality of Research" which are measured by research publications.

Increasing budgetary constraints together with the rising costs of higher education require improvements in productivity and efficiency of the higher education system as well as of HLIs in order to enhance the overall financial sustainability of the system (Ministry of Education Malaysia, 2014). Therefore, it is crucial for each MRUs to use its allocation wisely to produce better impacts and outputs. Evaluating the efficiency of universities is a key factor for effective allocation and utilization of research funding.

There is limited empirical study on the demographic factor contributed to research productivity and efficiency based on Malaysian University performance indicator and the influence of research culture in Malaysia. Most of the studies have been done in Europe (Kyvik & Olsen, 2008; Rørstad & Aksnes, 2015; Rauber & Ursprung, 2008) and North America (Gonzalez-Brambila & Veloso, 2007). Additionally, previous research have concentrated on the various aspects of this productivity but there have been few researches that took into account the input required to produce the publications, namely the efficiency of research (Dhillon, Ibrahim, & Selamat, 2015).

This research seeks to confirm previous research on productivity and measure the relevant inefficiencies to determine if a similar relationship exists for research inefficiency. The next section will discuss further on literature review from past studies base on this topics.

LITERATURE REVIEW

This literature review consists of two main topics. The first topic discusses on theories on relationship between demographic factor, productivity and efficiency and the second topics presents on research efficiency using DEA model.

Theories on relationship between demographic factor, productivity and efficiency

Psychologists, sociologists, and economists explained the possibility of the existence of an age-publishing productivity relationship differently. Scholars have developed three non-exclusive theories that might explain the age-publishing productivity relationship; the cumulative advantage theory, the utility maximizing theory and the obsolescence theory.

Kyvik and Olsen (2008) mentioned three theories that define relationship between age and productivity which are the cumulative advantage theory, the utility maximizing theory and the obsolescence theory. Later on (Kyvik & Olsen, 2008) added three more theories and hypothesis on his study which are the seniority burden hypothesis, the age decrement hypothesis and the intellectual deadlock hypothesis. Table 1 describes summary for each theory presented in the studies:

Table 1: Description of summary for each theory

No	Theory/Hypothesis	Description
1	the cumulative advantage theory	As age increase, the productivity of researchers will decrease. This is due to lack of professional recognition which slowly leads to lower productivity
2	the utility maximizing theory	As age increase, the productivity of researchers will decrease because expected utility time on research will reduce
3	the obsolescence theory	There is very little age decrement in intelligence and in functions that do not require fast responses or are affected by reaction times
4	the seniority burden hypothesis	The more experienced academic staff are, the more duties they are expected to engage in. This then reduce the time available for research
5	the age decrement hypothesis	Older scientists on average function on a lower intellectual and physical level than their younger colleagues. They are also exposed to age-related physical problems and illnesses which may hamper or slow down their engagement in research.
6	the intellectual deadlock hypothesis	Older academic staff are not able or willing to reorient their research towards new scientific or social problems.

A lot of studies have been categorized determinants of research output productivity into few categories. Dhillon et al. (2015) categorized on three core factors which are personal factors, environmental factors and behavioral factors. (Hedjazi & Behravan, 2011) used three components of productive research organization which are individual, institutional, and demographic characteristics. This model was developed based on Bland, Center, Finstad, Risbey, and Staples (2005) model.

Efficiency and productivity are two different concepts, but related through the fundamental of efficiency as being relative relationship between the observed productivity of a unit and the maximal achievable productivity for the type of activity in question (Førsund, 2016).

Research Efficiency Data Envelopment Analysis (DEA) Model

Charnes, Cooper, Lewin, and Seiford (1994) is the founder of DEA in 1978. It is applicable to measure the relative efficiency of a group of homogenous firms or decision making units (DMUs) (Kuah & Wong, 2011).

DEA is an analytical and non-parametric technique that can be used to identifying best practice performance in the use of resources amongst a group of like organizations and most commonly applied in government organizations. DEA can also readily incorporate multiple outputs and be used to calculate technical and scale efciency using only information on output and input quantities. In this study, we used technical efciency to measure the efficiency based on allocation of the physical inputs at its disposal for a given level of output. In other words, technical efciency refers to the use of productive resources in the most technologically efcient manner (Katharaki & Katharakis, 2010).

Current studies shows two types of using DEA methodology in universities; one is the analysis have been done to compare data from different universities and the other one is to measure efficiency within academic departments in the same universities (Agha, Kuhail, Abdelnabi, Salem, & Ghanim, 2011; Aziz et al., 2013). Abbott and Doucouliagos (2003); Aziz et al. (2013); Katharaki and Katharakis (2010) measure technical efficiency while (Kuah & Wong, 2011; Agha et al., 2011). Table 2 is the summary of literature review based on this two types of using DEA methodology in universities:

Previous studies shows that findings from the measurement of efficiency differs based on the input and output selection. As examples, Aziz et al. (2013) found that social science based departments on average perform better than the science based departments based on her study across public universities in Malaysia while Moreno and Tadepalli (2002) conclude that 22 out of 42 academic departments were relatively efficient.

This study will focus on measurement of productivity and efficiency within academic departments in the same universities. There is limited empirical study on the research efficiency between science and social science departments based on Malaysian University performance indicator and the influence of research culture in Malaysia. Most of the studies mentioned in Table 2 measure efficiency on general efficiency of the universities, not specifically on research efficiency. This research is expected to contribute to the body of knowledge through the aspect of efficiency.

RESEARCH METHOD

UPM was selected as the sampling pool due to availability of data. Due to standard KPIs given by the ministry of higher education across all MRUs, results should be applicable across other MRUs. This study applies DEA to evaluate the technical efficiency between science and social science fields, while taking into account the researcher academic position. All data used in this study were gathered from secondary sources specifically compiled from the Knowledge Management Portal, managed by the Research Management Centre of UPM and Database the Registrar of UPM which includes all achievements of various types by UPM employee. All researchers that published at least once between the years 2010 to 2016 in CIJ, non-CIJ or books and chapters in books with an academic position (lecturer, senior lecturer, associate professor or professor) attached to a science or social science faculty or research centre were selected as the sample totalling 10,655. Their corresponding research grants received were then compiled and their relative efficiency was then measured by applying DEA. Research output data then will be categorized by their academic position (Professor, Associate Professor, Senior Lecturer and Lecturer) in the fields of Science and Social Science. T-tests were used to determine significance of variance and non-parametric tests was also conducted to ensure robustness. DMU selected was individual researcher. The input and output variable are research grant received by the receiver and number of publications respectively. Four different efficiency measures were calculated corresponding to efficiency in CIJ, non-CIJ, books and chapters in books. The efficiency of producing the outputs was calculated separately due to the difference in focus between the two fields. Basic research for science fields such as physics or chemistry has an international frontier as opposed to the social sciences and humanities fields that is primarily oriented at the national or regional topics (Nederhof, 2006).

FINDINGS AND DISCUSSION

Research output measured by publications on CIJ journals are shown in Figure 1 and the corresponding research efficiency are shown in Figure 2. We find that over the duration of the study (2010 to 2016), academics in the science field publish much more than academics in the social science field for all positions but social science academics are more efficient at using grants to produce CIJ journal publications. Research productivity increases as academics rise in their positions, indicating support for the cumulative advantage theory but falls slightly at the end of the career suggesting support for the utility maximising theory as well. Figure 3 and Figure 4 depicts the research output by years for the science and social science field respectively. Both show consistent trends over seven years, with only science field for the year 2011 and 2012 showing no decrease at the position of professor.

Table 2: Description of summary for each theory

Author	Type of Research	Location	Input	Output	Type of Efficiency	Duration for Data Collection/ Sample Size
Abbott and Doucouliagos (2003)	Across Universities	Australian Universities	1) Research 2) Teaching	1) Number of Academics Staff 2) Number of Non-Academics Staff 3) Expenditure other than Labor Inputs 4) Value of non-current assets (rough proxy on university's capital stocks)	technical and scale efficiency	1995 All Australian Government Universities
Kuah and Wong (2011)	Within university	UTM	1) Teaching efficiency -Number of academic staffs -Number of taught course students - Average students' qualifications (CGPA) -University Expenditure 2) Research efficiency -University Expenditure -Number of Research Staffs Average research staffs' qualifications -Number of research students -research grants	1) Teaching efficiency -Number of graduates from taught courses - Average graduates' qualifications (CGPA) -Graduation Rate -Graduates' employment rate 2) Research efficiency -Number of graduates from research -Number of publications -Number of awards -Number of intellectual properties	Relative efficiency	Hypothrtical examples of 30 universities

Table 2 Continuee..

Author	Type of Research	Location	Input	Output	Type of Efficiency	Duration for Data Collection/ Sample Size
Katharaki and Katharakis (2010)	Across Universities	Greek Universities	1) The number of academic staff with teaching and research activity 2) The number of non-academic staff 3) The number of active registered students 4) Operating expenses-other than labour inputs. This includes expenditure on energy, non-salary expenses, and administration services, buildings and grounds, libraries and student services.	1) The number of graduates, including undergraduate, graduate and post-graduate degrees 2) The research income	technical efficiency	2004 20 public universities which represents 91% of the public universities
Aziz et al. (2013)		Across Universities	Public Universities in Malaysia	1) Number of academic staff 2) Number of non academic staff 3) Operating expenses	1) number of Graduates 2) total amount of research grant 3) academic publication technical efficiency	2011 22 academic departments
Agha et al. (2011)	Within university	Islmaic University in Gaza	1) operating expenses 2) credit hours 3) training resources	1) number of graduates 2) promotions 3) public service activities	Relative efficiency	2004-2006 30 departments

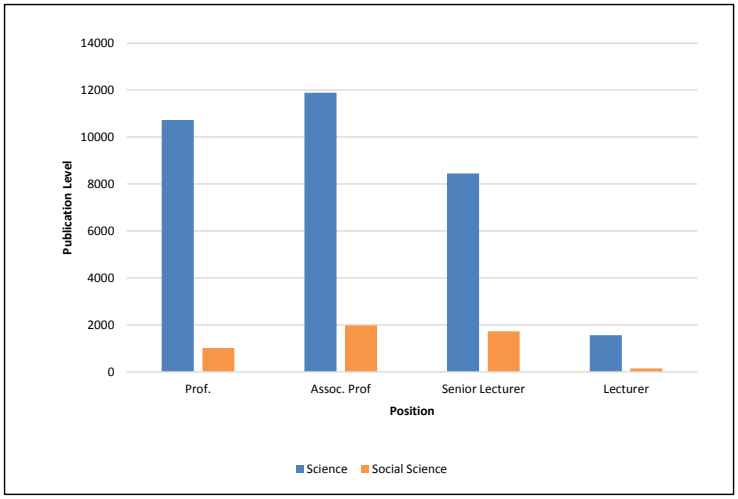

Figure 1. Research output by position (CIJ)

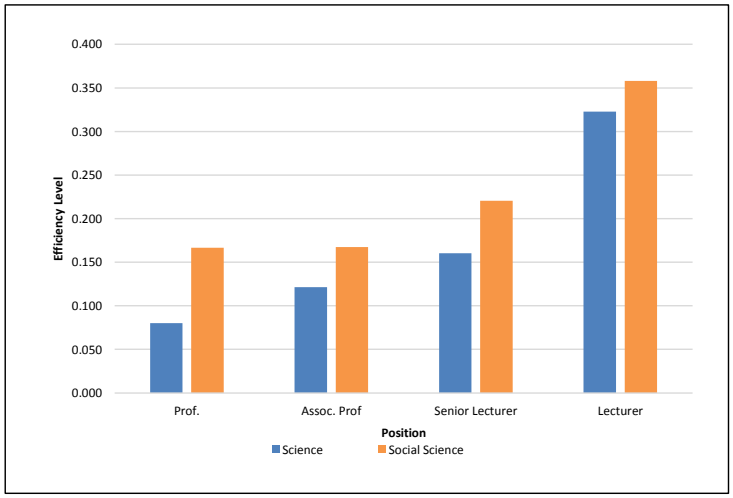

Figure 2. Research efficiency by position (CIJ)

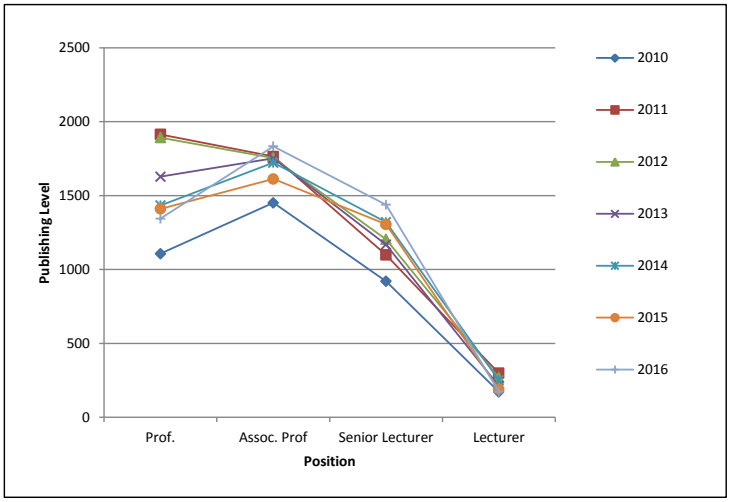

Figure 3. Research output for science by position (CIJ)

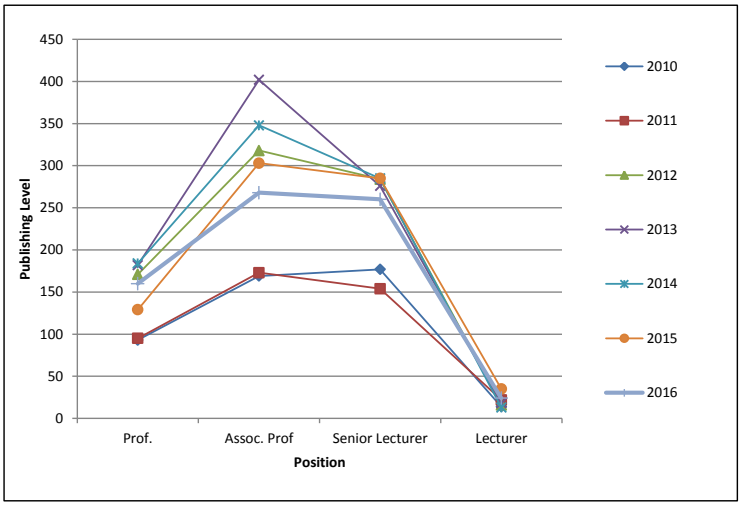

Figure 4. Research Output for social science by position (CIJ)

For publications in non-CIJ journals, publications is increase with position. Figure 5 shows research output on non-CIJ journals by position, while Figure 6 shows its efficiency. Researchers in the science field generally publish more than their counterparts in the social science fields across all positions except for the senior lecturer positon but there generally no difference in efficiency except for the lecturer position which science academics are more efficient. Figure 7 and Figure 8 depicting the non-CIJ journal year on year for the science and social science filed respectively. For both science and social field, the trend is incline and seen with a peak at the Associate Professor position and sudden drop when at the Professor position. This is due to the seniority burden hypothesis which stated that the more experienced academic staff are, the more duties they are expected to engage in. Seniority and experience bring about an accumulation of tasks and duties that reduce the time available for research (Kyvik & Olsen, 2008).

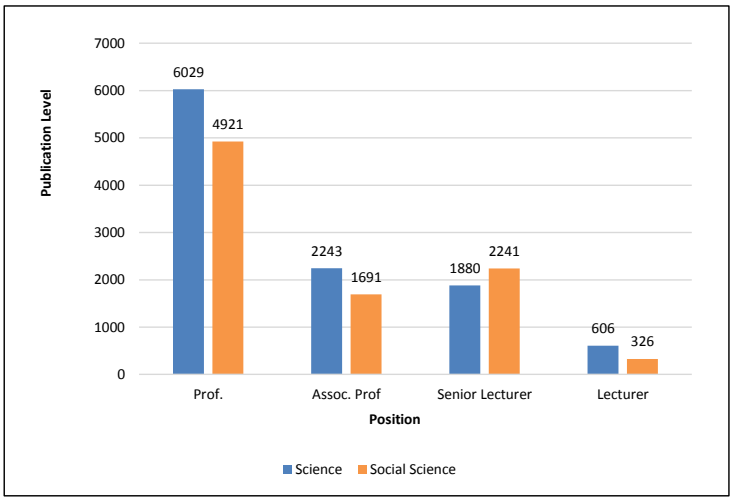

Figure 5. Research output by position (Non-CIJ)

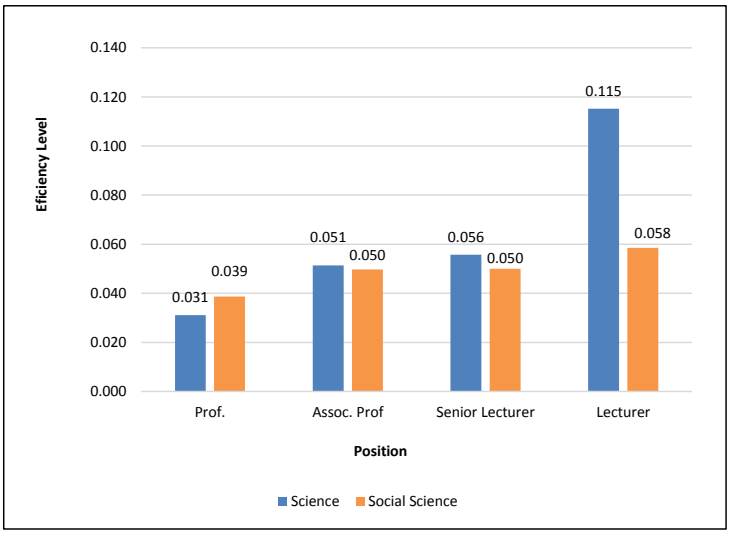

Figure 6. Research efficiency by position (Non-CIJ)

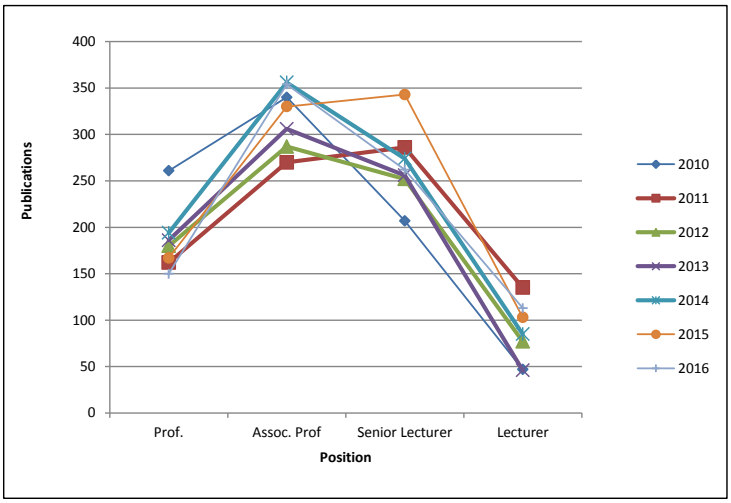

Figure 7. Research output for science by position (Non-CIJ)

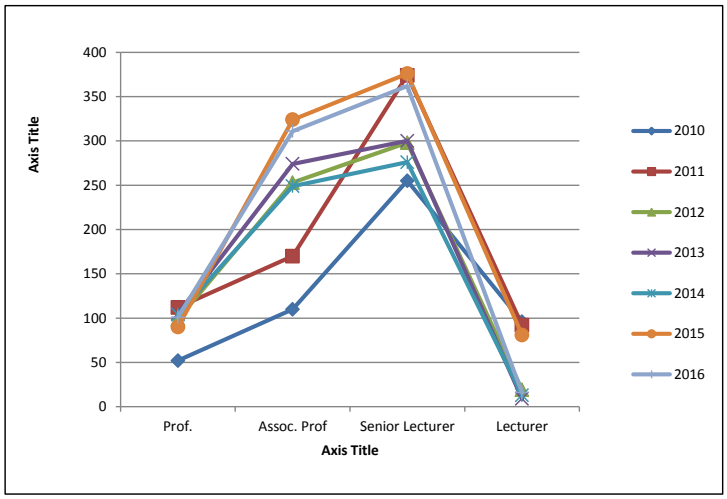

Figure 8. Research output for social science by position (Non-CIJ)

Research output on books by academic position of the authors are depicted in Figure 9 while their corresponding efficiency is shown in Figure 10. Academics in the social science field publish more book chapters than their counteparts for all ages except for the positions of professor but those is the science field are generally more efficient except for the position of professors. Academics in the science field are more efficient for all positions except for the professor position where there is no difference. Figure 11 and Figure 12 shows the trend throughout the year for research output on books for both science and social science. It demostrates that the highest publication in books for both clusters is for the position of Senior Lecturer.

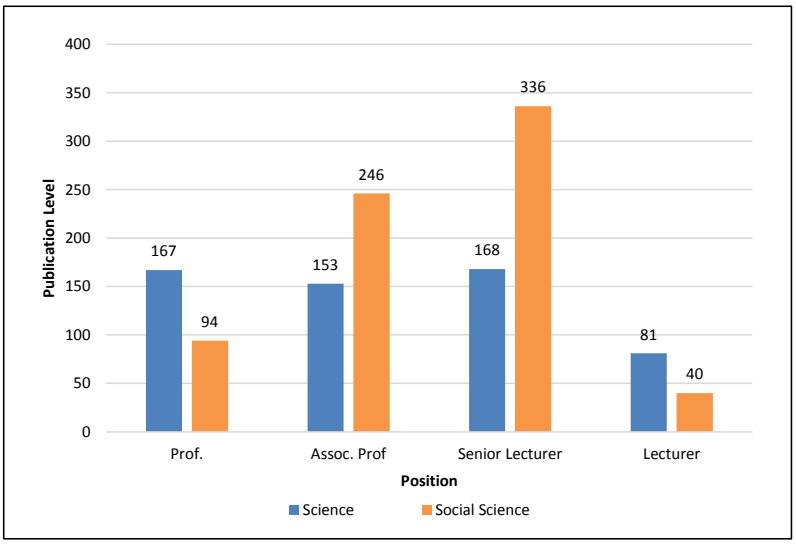

Figure 9. Research output by position (Books)

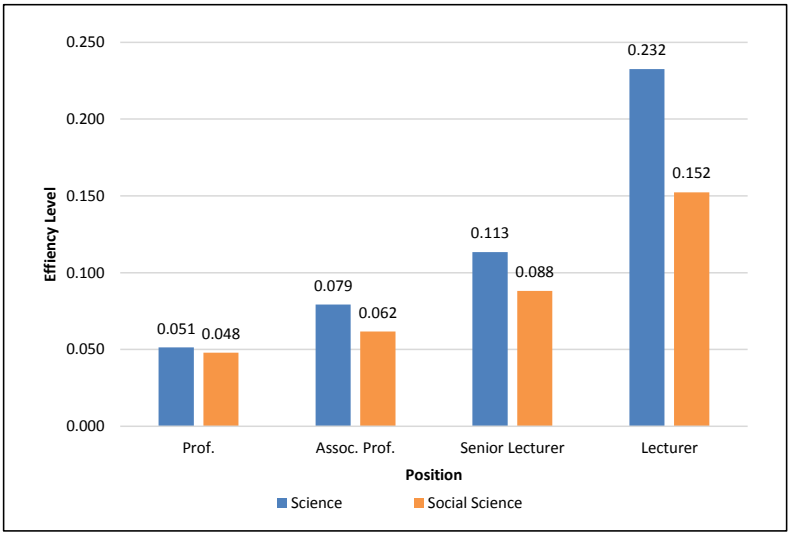

Figure 10. Research efficiency by position (Books)

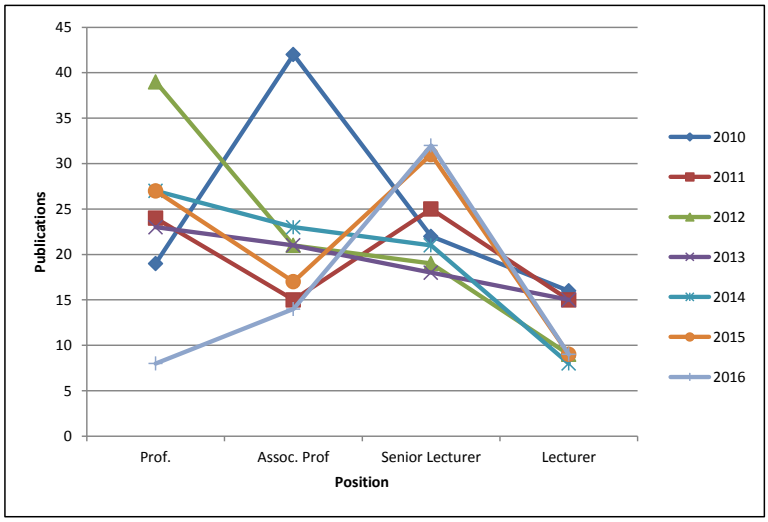

Figure 11. Research output for science by position (Books)

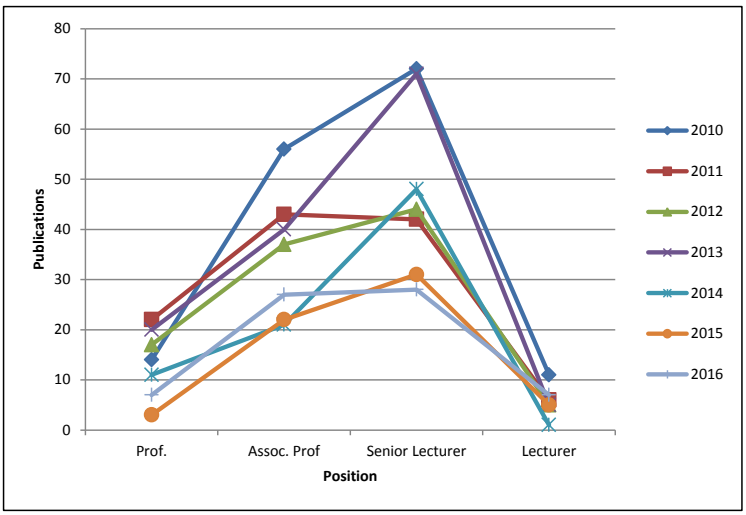

Figure 12. Research output for social science by position (Books)

Research output on book chapters by position are depicted in Figure 13 while their corresponding efficiency is shown in Figure 14. For the science field, there is a initial increase after the position of lecturer but productivity remains the same for the positions senior lecturer to professor. However, for the social science field, after and initial increase, productivity generally declines. Academics in the science field are generally more efficienct except for the professor position which has no difference. Generally for both fields, efficiency declines and position increases. The trend for publication in book chapters are depicts in Figure15 and Figure16 for science and social science. Similar with publication in books, publication in books for social science is for the position of Senior Lecturer, while for Science the highest publication in book chapter divided almost equally for position Senior Lecturer and Associate Professor.

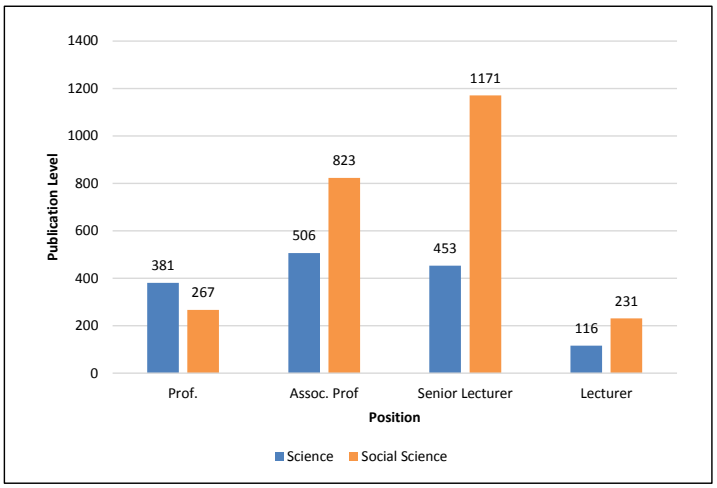

Figure 13. Research output by position (Book Chapters)

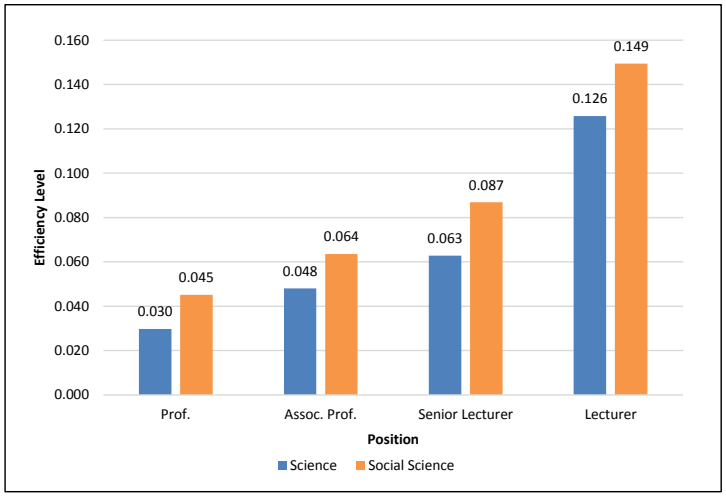

Figure 14. Research efficiency by position (Book Chapters)

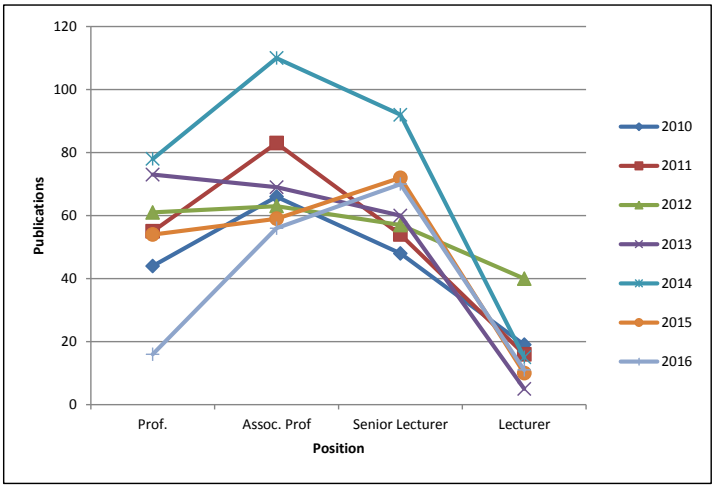

Figure 15. Research output for science by position (Book Chapters)

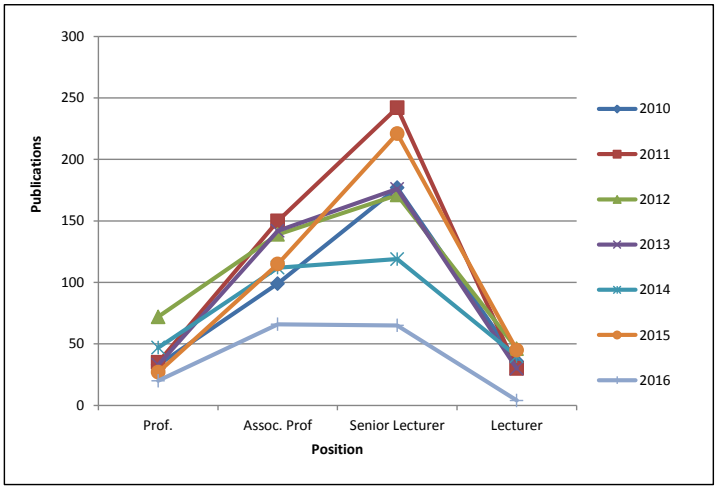

Figure 16. Research output for social science by position (Book Chapters)

Findings shows that lecturer position for both science and social science have the highest efficiency of all type of publications as been stated in Table 3. This may due lecturer position received less research grant but they published more due to promotion factors.

Table 3: Results of Simple Linear Regression Analysis Equations Coefficients$_a$

Position v/s Research Efficiency	Science				Social Science			
	Professor	Associate Professor	Senior Lecturer	Lecturer	Professor	Associate Professor	Senior Lecturer	Lecturer
CIJ				/				/
non-CIJ				/				/
Book				/				/
Book chapters				/				/

CONCLUSION AND IMPLICATIONS

It is crucial for each MRU's to use its allocation wisely to produce better impacts and outputs. Evaluating the efficiency of universities is a key factor for effective allocation and utilization of research funding. Findings shows that research inefficiency for the both science and social science fields generally worsen with higher academic positions. The effect for science field is more pronounced for CIJ, non-CIJ and books.

This study will definitely adding new knowledge on the relationship between age and research productivity based on Malaysian environment and culture. It also will be a guideline for policy formulation in public university in managing talent pool based on age influence towards research productivity. This new indicator can be benchmarking to others university especially new age of university in Malaysia.

For further study, other demographic factors such as age and gender can be included as determinants for the productivity efficiency in research. Further study also can expanded for output in innovation aspects such as patent, industrial design and other types of intellectual properties.

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