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Quantitative Study on Australian Academic Science

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Abstract

As at the end of 2009, 50 million scholarly papers were in existence, and changes in the global higher education sector are seeing this number grow rapidly. With the impact of university ranking schemes, dramatic changes have occurred in the academic publication system; both the number of publications, and the number of scholars, are increasing rapidly. In this research, we conduct a focused study on the quantitative relationships in Australian academic science. Sample data is selected from three institutions, representing three types of universities in Australia: a leading university, a middle-tier university, and a non-comprehensive university. For our analysis, bibliometric data for 32,056 scholars and 353,334 publications are downloaded. The results show that varying growth rates for scholars (5.6%, 6.1%, and 7.7%) and journal publications (6.7%, 7.4%, and 9.7%) for the leading university, the middle-tier university, and the non-comprehensive university respectively. We also evaluate how scholarly publications differ across these three Australian universities types from six aspects: average number of publications per scholar, percentage of first-authored publications, collaboration pattern, average SJR score of publishing journals, percentage of Quartile category of publishing journals, and average citation per publication. Lastly, we consider how the scholarship life-cycle varies in Australian universities in terms of publishing age, thus establishing the quantitative relationship between scholarship life-cycle and publishing performance in Australian universities.

Keywords

Scholars, Publications, Australian Universities, Scholarship Life Cycle, Collaboration, Academic Science,

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Introduction

Since the release in 2003 of the Shanghai Jiao Tong University Academic Ranking of World Universities (ARWU), university rankings continue to have a pervasive effect on the ways in which individual institutions compete in the global higher education market. Numerous global university ranking schemes have swiftly evolved. Major media organizations, top universities and research organizations, and even governments, are involved to develop different methodologies for global university ranking, including Times Higher Education World University Ranking (THE) (Times Higher Education, 2016), QS World University Rankings® (QS) (Quacquarelli Symonds Limited, 2016), USNWR Best Global Universities Ranking (USNWR) (U.S. News & World Report, 2016), and so on. Fundamentally global university rankings are used to compare educational performance and productivity nationally and internationally, and measure educational quality and excellence (Hazelkorn, 2009, 2013). Additionally, global university rankings are often used as an indication of a nation's global competitiveness, given the importance of higher education to social and economic growth and innovation (Hazelkorn, 2009; Marginson & Van der Wende, 2007).

Giving rise to differing perspectives on the appropriateness, and methodology for constructing, global university rankings, each ranking scheme has its own specific indicators and calculation formulas. For example, based on ARWU, higher education is about scientific research and Nobel Prizes (Shanghai JiaoTong University, 2016); from the perspective of THE, higher education is primarily about building reputation and international marketing (Times Higher Education, 2016); and based on USNWR and QS, 60% of the final ranking score is attributed to research outputs (Quacquarelli Symonds Limited, 2016; U.S. News & World Report, 2016). Although rankings can be capricious, research output, as an indicator, is the highest weighted measure among all the ranking schemes. Regardless the ranking methodology used, research output is primarily measured by the quality (citation) and quantity (number) of scholarly publications (Marginson, 2007).

Due to the importance of scholarly publication in the university rankings, many universities set annual publication criteria for their academics (Sullivan, 1996), to enable the institution to be more competitive in the global higher education market. In addition to the pressure from universities, academics are intrinsically motivated for publication. Via scholarly publication, academics can receive recognition and esteem by the scholarly community, obtain career promotion, and secure funding opportunities for future research (Fox, 1983; Sullivan, 1996). However, the most significant reason for academic publications are for knowledge dissemination and advancement (Fox, 1983; Jacot, 1937; McGrail, Rickard, & Jones, 2006; Sullivan, 1996). These reasons are long established, and persist to act as drivers for publication growth.

From the first model of the modern journal, *Le Journal des Sçavans*, published in France in 1665, the number of scholarly publications has grown steadily. It is estimated that there were approximately 50 million scholarly publications in existence at the end of 2009 (Jinha, 2010), with a growth rate of 2% (Björk, Roos, & Lauri, 2008) to 3% (Jinha, 2010) per year contributing to an impressive amount of scholarly inheritance. Scholarly publications are typically created via the academic publication system. A large proportion of publications are published through academic journals, which function as forums for the introduction, and presentation for scrutiny, of new knowledge, and the critique of existing knowledge (Blake & Bly, 1993). Mabe and Amin (2001) studied the pattern of growth in the number of academic journals worldwide, identifying three key development periods between 1900 and 1996. These three episodes are from 1900 to 1944, from 1944 to 1978, and from 1978 to 1996. The compound annual growth rates for each episode are 3.30%, 4.68% and 3.31% respectively. More recent work from Gu and Blackmore (2016) indicates that we are experiencing the second academic knowledge boom, with academic journals growing at an average rate of 4.7% from 1986 to 2013. This rate is akin to that seen during the previous boom following World War II.

The Australian Censuses of Population and Housing conducted in November 2008, conducted by Australian Bureau of Statistics, reported that the number of academic staff in Australian universities grew from 13,935 in 1976, to 22,707 in 1986, 29,008 in 1991, to 35,980 in 2006 (Hugo, 2008). This represents a 158% increase in the number of academics in Australia over this 30-year period. Similar to the growth in the number of academic journals and scholarly publications in the academic publication system, the number of scientists has been rapidly growing in Australia. While these figures provide a picture of growth at the sector level, more detailed analysis, at the institutional level, is lacking.

In this research, we consider how individual universities vary in the amount and pattern of growth in academic publishing. A case analysis of three Australian universities, representing a leading university, a middle-tier university, and a non-comprehensive university (Marginson, 1997) is formed based on the analysis of the growth of Australian scholarly publications and scholars, and the analysis of the quantitative relationships among scholarly publication, scholars, and three universities in Australia. In the following background section, we provide the justification for the selection of three Australian universities. Section 3, "Methodology", follows where we describe the data sources, data collection, and the research methodology. This is followed by the presentation of results and the discussion of findings in Section 4, and finally conclusions, limitations and possible future work are presented in Section 5.

Background

Three Australian Universities

For the purpose of comparing the scholarly output from universities, three Australian universities of differing scales are selected: a leading university, a middle-tier university, and a non-comprehensive university. These three university types are classified as *Sandstone*, *Wannabee Sandstone*, and *New University* respectively by (Marginson, 1997). The *Sandstones* claim leadership in research, the academic disciplines, and professional training. The *Wannabee Sandstones* make the same claim to social prestige as the sandstones, but with less plausibility and conviction despite their academic achievements. And the *New Universities* focus on access, teaching quality, customer friendliness and regional factors, but they struggle to compete on the basis of reputation, research or ultra-employability. In this research, the leading university is called as *U1*, the middle-tier university is called as *U2*, and the non-comprehensive university is called *U3*.

Besides the university typology defined by Marginson (1997), the 2016 global university rankings also show these three universities achieve consistent results across all ranking schemes. The ranking results from the most well-known four university ranking schemes are listed in Table 1.

Ranking Scheme	*U1*	*U2*	*U3*
ARWU (Shanghai JiaoTong University, 2016)	#1-#50	#301-400	fall out of top 500
THE (Times Higher Education, 2016)	#1-#50	#201-#300	#501-600
QS (Quacquarelli Symonds Limited, 2016)	#1-#50	#201-#300	#551-600
USNWR (U.S. News & World Report, 2016)	#1-#50	#301-400	fall out of top 700

Table 1. Ranking results for *U1*, *U2*, and *U3* at four global university ranking schemes

In the late 1980s, institutional research policies were introduced to Australian universities, culminating in the introduction of the Excellence in Research Australia (ERA) evaluation and funding scheme, which was announced in 2008 and implemented in 2010 (Graham, 2008; Hicks, 2012). The funding incentives encouraged a higher rate of international collaboration, and higher journal publication output, with concerns raised over a real or potential decline in the impact or quality of this increased output (Butler, 2003a). With Australian government funding to universities linked to publication output from the mid-1990s, a dramatic increase in the number of publication outputs has been observed, however, an increase in author collaboration on publications is also likely to be a contributing factor (Haslam, Stratemeyer, & Vargas-Sáenz, 2016). Additionally, research conducted in 2003 suggests that with no initial incentive for higher ranked journal publications, the earlier growth in publication output in Australia occurred at the lower end of the impact scale (Butler, 2003b). In addition to institutional and Australian policy changes, higher education institutions seek to compete in the increasingly global higher education market, and insights into how the system is growing and changing are useful strategic decision-making inputs. The primary purpose of our research is to investigate the quantitative relationships among scholarly publications, scholars, and universities in Australia. In order to obtain more specific answers, we seek the answers to the following specific questions:

- RQ1: What changes have occurred in the growth of scholars, and their associated scholarly publications, in Australia in the last four decades?
- RQ2: How do scholarly publications differ across Australian universities?
- RQ3: How does the scholarship life-cycle vary in Australian universities in terms of publishing age?
- RQ4: What is the relationship between scholarship life-cycle and publishing performance in Australian universities?

Many potential sources of data in relation to scholarly publications are available to assist in answering these questions. In this research, we use *Scopus* and *SCImago Journal & Country Rank* (*SJR*). Each database provides us with voluminous detailed information on scholars and their publications, and their use in this research is described in the following methodology section. In this research, we limit academic publications to (peer-reviewed) journal articles, and scholars are restricted to the three universities: *U1*, *U2*, and *U3*.

Methodology

Data source

There are a variety of bibliographic databases available to obtain data on academic publishing. Web of Science (WoS), Scopus, and Google Scholar (GS) are recognized as the three main scholarly bibliographic data sources (Alonso, Cabrerizo, Herrera-Viedma, & Herrera, 2009; Meho & Yang, 2007). Each has developed its own metrics to measure the value or quality of academic papers or academic journals. Multiple studies show that *Scopus* has the widest coverage in peer-reviewed scholarly journals and publications (Gu & Blackmore, 2017; Jacso, 2005). A recent study by Larsen and von Ins (2010) shows that the Science Citation Index (SCI) and Social Science Citation Index (SSCI) provided by WoS has a decreasing coverage. Although GS is a powerful search engine to access scholarly publications from all publishers, with greater coverage, it includes conference proceedings, open access archives, publications published on the net, and even academic tutorials (Larsen & von Ins, 2010). This means GS indexes work from sources that may not be considered as valid academic work. Therefore, Scopus is chosen as the data source for this study.

To locate relevant scholars and journal publications for this study, we conducted our searches over *Scopus*, which requires a paid subscription for download on the Web (Elsevier, 2016). From the Web interface, searches can be conducted for documents, authors, and / or affiliation. The interface allows searches through the pre-set search forms, or advanced searches via search queries.

SCImago Journal & Country Rank (*SJR*) provided by *Scopus* is free to download and available (Scopus). From the Web interface, the parameters for the search are *Subject Area*, *Subject Category*, *Region / Country*, and *Year*. The available *SJR* reports are dated from 1999 to 2015, allowing for journal data to be extracted for this period.

Data collection and cleansing

Previous studies on Australian academic research outputs are restricted within limited disciplines (Mishra & Smyth, 2013), limited timeframes (Murphy, 1995), or limited journal sources (Bourke & Butler, 1996; Butler, 2003a). To extend the research space, the publication outputs for this study cover all *Scopus* journals across 41 years, over three different levels or types of universities. The Data collection includes two components: *Scopus* and *SJR*. The data collection was conducted in July 2016 in four steps, which are described below.

In the first step, a total of 32,056 scholar records were downloaded from *Scopus* for the three universities: *U1*, *U2*, and *U3*. From the interface of *Affiliations* on *Scopus*, three searches were conducted based on the full name of the universities. The research result shows a list of relevant universities. clicking on one university, *Scopus* redirects to the main page for the specific university, where an author link allows us to access all authors currently belonging to the specific university. Scholars who worked at another university but currently work at the specific university are considered in this study, however their previous articles published at the previous university are not considered in this study. And scholars who worked at the specific university but have left for another university are not considered in this study.

For the second step, publication data from the scholars downloaded from step 2 is collected from *Scopus*. Each scholar has a link to their associated publications. Through the links, we collected a total of 353,334 publication records, out of which, 276,580 were from *U1*, 62,964 from *U2*, and 13,790 from *U3*.

For the third step, we downloaded *SJR* reports based on calendar years from 1999 to 2015. All unique journals across 17 years are combined for this research. This resulted in a consolidated total of 28,944 unique *SJR* journal records.

Lastly, we conducted data cleansing over scholar, publication, and journal data. As previously stated, our research is targeting journal publications, therefore, we extracted the journal publications, and the scholars who published in journals, from the general *Scopus* data collection. In total 284,128 journal publications from 28,059 scholars are discovered in three universities. After removing the duplicated publications, there are 189,488 unique journal publications in total.

The workflow of the data collection and cleansing process is shown in Figure 1.

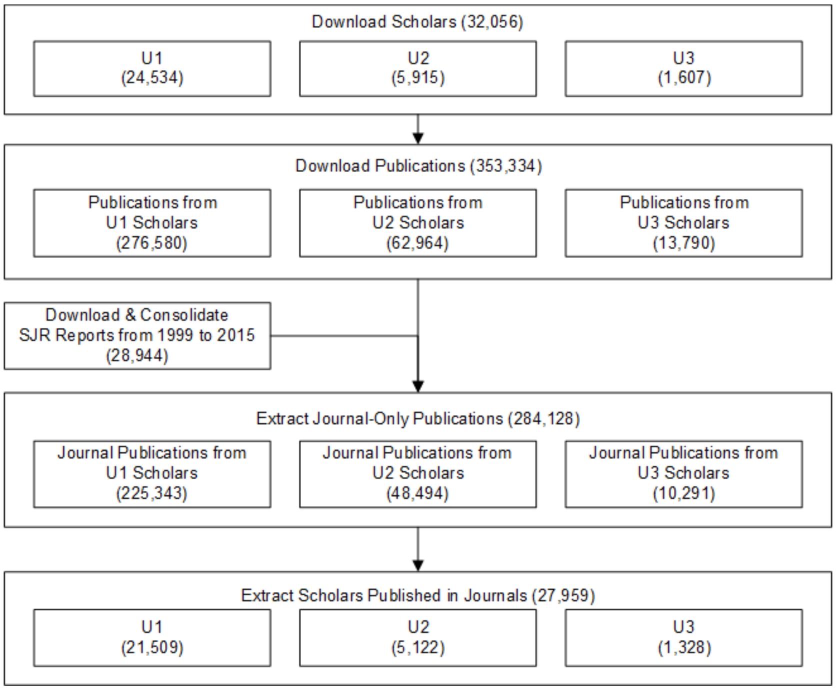

Fig. 1 Workflow of data collection and cleansing on scholars and publications dated in July 2016

The downloaded details for each university are listed in Table 2.

	U1	U2	U3	Total
Total Number of Scholars	24,534	5,915	1,607	32,056
Total Number of Publications	276,580	62,964	13,790	353,334
Number of Scholars Published in Journals	21,509	5,122	1,328	27,959
Number of Journal Publications	225,343	48,494	10,291	284,128
Number of Unique Journal Publications (excluding collaboration from same university)	147,762	33,112	8,614	189,488

Table 2. Results of data collection and cleansing on scholars and publications dated July 2016

Results and discussion

The analysis and results relating to the four research questions presented in the Background section are provided and discussed in sequence order in this section.

RQ1: What changes have occurred in the growth of scholars, and their associated scholarly publications in Australia in the last four decades?

To find the growth pattern in Australia academic science, we investigate the growth rate of scholars and journal from three representative universities.

Previous work has revealed that globally, academic science is currently experiencing the second knowledge boom with journals growing at an average rate of 4.7% from 1986 to 2013 (Gu & Blackmore, 2016). This study includes the time frame from 1974 to 2014, which covers both academic booming period and normal development period (Mabe & Amin, 2001). Through quantitative study over a different time frame, we can observe the growth difference in the number of publications between two periods.

Considering the possible latency in data collection for *Scopus*, publication data in 2015 and 2016 are not considered for this research. As a result, we use the data of journal publications published by scholars from *U1*, *U2*, and *U3* from 1974 to 2014 to analyze the growth rate of publications for these three universities.

Growth rate of scholars from three Australian universities

The number of scholars who have journal publications from three representative Australian universities from 1974 to 2014 inclusive, based on the calendar year, are extracted. The data are presented on a scatter plot in Figure 2 to show the growth trends. Three exponential trendlines are introduced to this chart to demonstrate the growth rates for the three Australian universities.

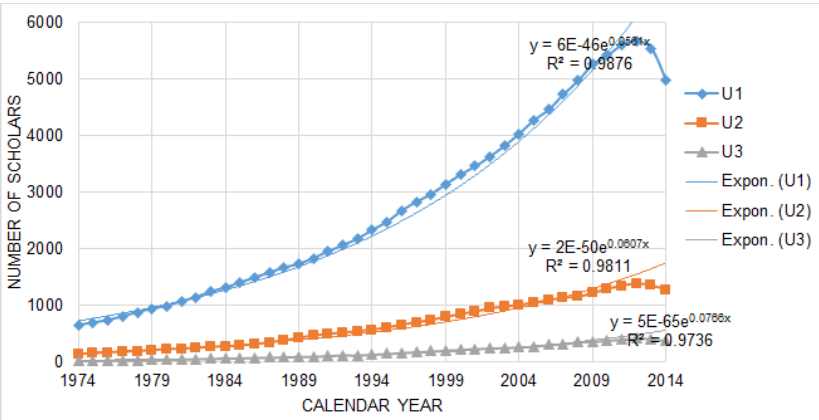

Fig. 2 Growth of scholars from three Australian universities from 1974 to 2014

An interesting phenomenon from Figure 2 is that the number of scholars for all three Australian universities are dropping from 2014. This could be related to the reduced higher educational funding from Australian government (Regional Universities Network, 2016), however, it more likely reflects a lag in publication data in bibliometric databases due to publishing and peer review processes. In Figure 2, exponential trendlines are fitted to the *U1* data (R-square=0.987), the *U2* data (R-square=0.981), and the U3 (R-square=0.974), which indicates excellent model fit. Based on the three exponential trendlines, the growth rates of scholars are 5.61% for *U1*, 6.07% for *U2*, and 7.66% for *U3*.

Growth rate of publications from three Australian universities

Journal publications from *U1*, *U2*, and *U3* from 1974 to 2014 are used to analyze the growth rate of publications from three Australian universities.

Firstly, the number of unique journal publications from the three Australian universities from 1974 to 2014 inclusive, based on calendar year, are extracted. These data points are then presented on a plot in Figure 3 to show the growth trends. Three exponential trendlines are introduced to this chart to demonstrate the growth rates for *U1*, *U2*, and *U3*.

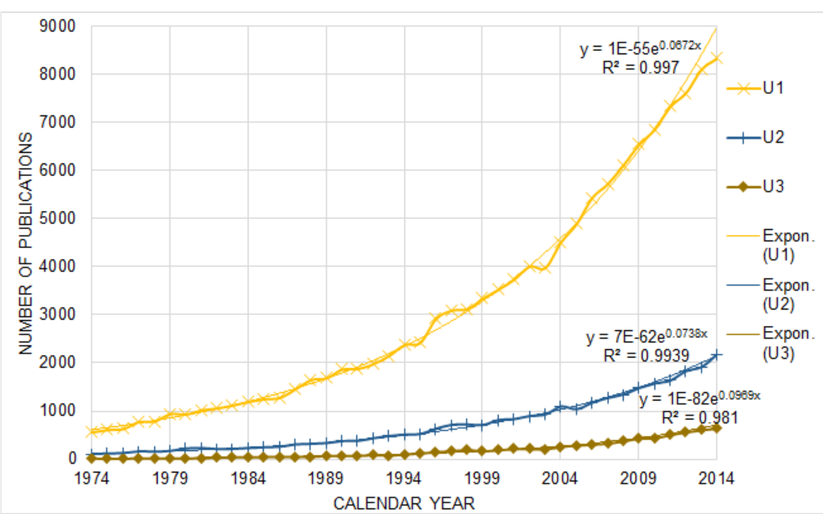

Fig. 3 Number of publications and trendlines from three Australian universities from 1974 to 2014

From Figure 3, The exponential trendline fitting to the number of publications for *Mel*. shows a R-square value of 0.997 indicating an almost perfect fit. The exponential trendline over the number of publications for *U1* indicates a calculated result of growth rate of 6.72%. The exponential trendline fitting to the number of publications for *U2* shows a R-square value of 0.993, and a growth rate of 7.37%. The exponential trendline for *U3* shows a R-square value of 0.981, and a growth rate of 9.68%.

RQ2: How do scholarly publications differ across Australian universities?

In order to better understand the publication performance of scholars at each university, the journal publication data from the three universities is analyzed by: the average number of publications per scholar, the percentage of first-authored publications, the pattern of collaboration, the average SJR score of publishing journals, the percentage of publications by Quartile category, and the average citation per publication.

Average number of publications per scholar from three Australian universities

The number of publications and the number of scholars from these three universities from 1974 to 2014 inclusive, based on the calendar year, are extracted. The equation to calculate the average number of publications per scholar per year is: $y = \frac{X_p}{X_a}$ where X_p represented the number of publications in Year X, and X_a represents the number of scholars from the specific university in Year X. The calculated results are presented on a scatter plot in Figure 4 to show the changes from 1974 to 2014.

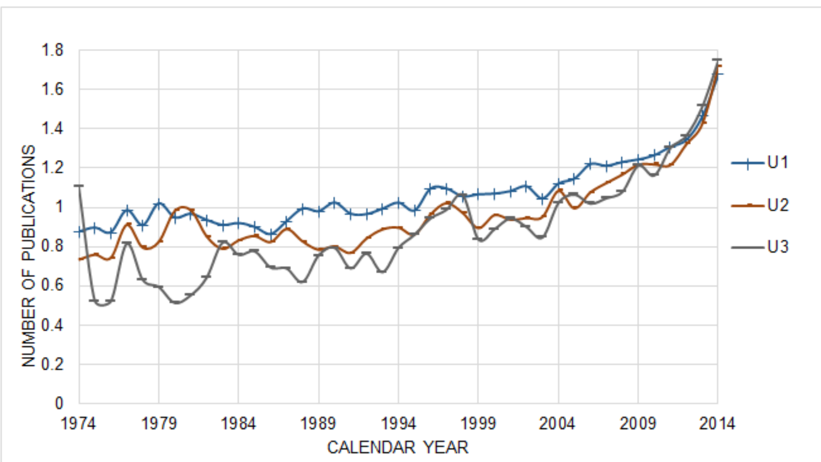

Fig. 4 Average number of publications per scholar from three Australian universities from 1974 to 2014

From this graph, it can be readily observed that the productivity of scholars from all three universities has increased over time. In particular, a general increase in the average number of publications per scholar from mid 1980s is evident, with this trend increasing during 1990s. A sharp increase is evident from approximately 2009, which coincides with the introduction of the Australian performance based funding system for higher education institutions (Hicks, 2012). While similar increased are observed across the three universities, we also note that the higher ranked U1 appears less variable. Interestingly we note that *U1* consistently had the highest productivity per scholar from 1974-2009, however the publication output per scholar converges for these three institutions from 2009 to 2014.

Percentage of first-authored publications from three Australian universities

A publication is considered to be first-authored by a particular university if the first listed author on a journal paper is from that particular university. The percentage of first-authored publications from each of the three Australian universities is calculated over the period from 1974 to 2014. The percentage of first-authored publications is calculated based on first-authored publications versus the number of publications in each specific year. The calculation equation for the first-authored percentage of Year X is: $y = \frac{X_f}{X_a}$ where X_f represents total number of first-authored publications in Year X and X_a represents total number of unique publications in Year X. The percentage of first-authored publications from 1974 to 2014 for *U1* is 42% (54265 / 129219), 45.6% for *U2* (13153 / 28815), 50.3% for *U3* (3728 / 7410). The calculated values in specific years are distributed on a scatter plot in Figure 5.

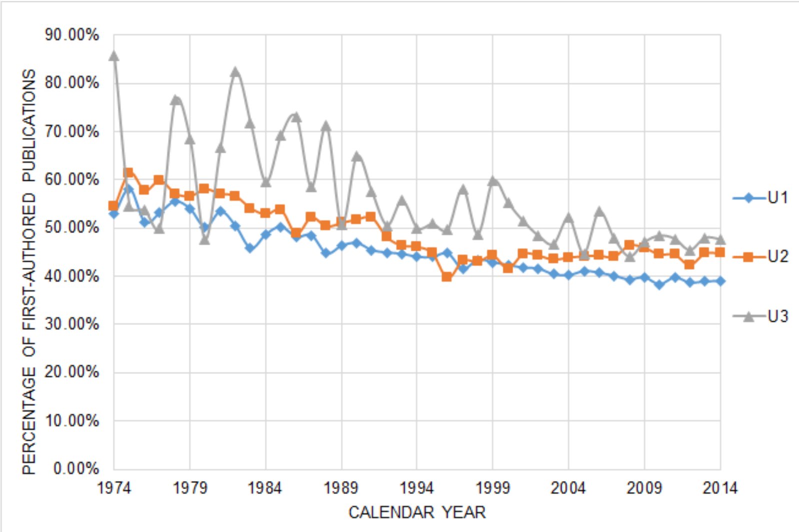

Fig. 5 Percentage of first-authored publications from three Australian universities from 1974 to 2014

From Figure 5, it can be observed that *U3* has the most variability in first-authorship over the years, and *U2* has a slightly higher first-author percentage than *U1*.

Collaboration Pattern from three Australian Universities

Collaboration pattern shows how scholars collaborate when they present research outcomes. In this research, collaboration is calculated based on the number of authors per publication. The percentage of collaboration is calculated based on total number of each collaboration pattern from the total number of publications from each university. In this research, only six collaboration patterns are considered, e.g. 1 author per document, 2 authors per document, 3 authors per document, 4 authors per document, 5 authors per document, and 6+ authors per document. The calculation equation for percentage of collaboration is: $y = \frac{X_a}{X_n}$ where X_a represents total number of publications with specific collaboration type and X_n represents total number of unique publications from a university. The percentage values of collaboration from the three universities are shown in Figure 6.

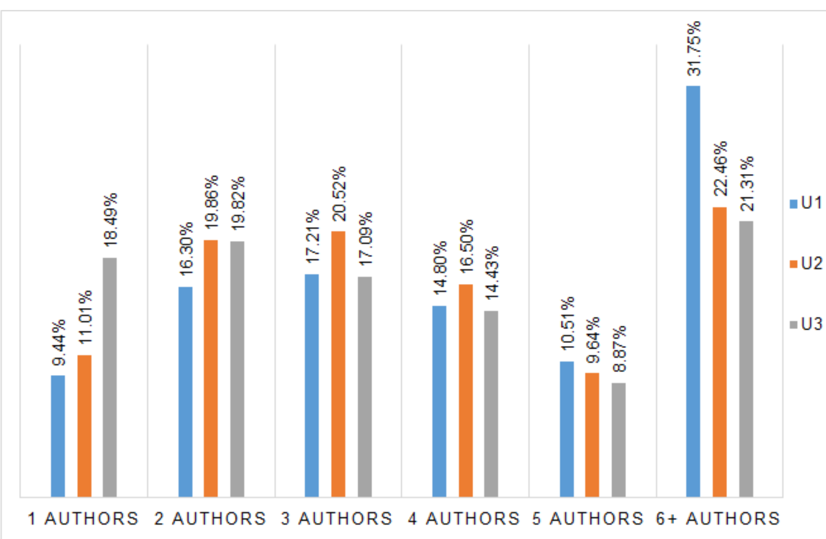

Fig. 6 Percentage of collaboration from three Australian universities

Figure 6 reveals that a team of two or three scholars is the most popular collaboration pattern across 40 years. It can be observed that *U1* engages more in team collaboration, while the lower-ranked universities have proportionally fewer publications with five or more authors, and a proportionally higher number of single authored papers.

To further investigate these results, the number of publications by each collaboration pattern are extracted, and the percentage of each collaboration pattern based on the calendar year for all three universities are calculated. The calculation results are shown in Figure 7.

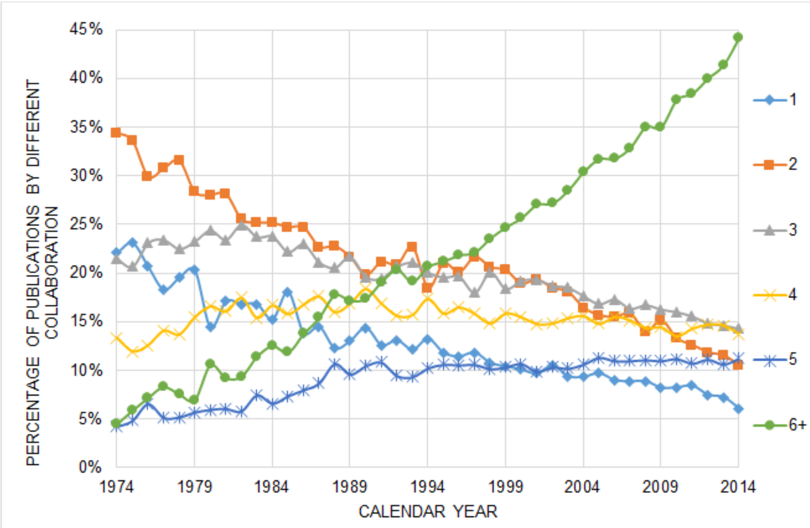

Fig. 7 Percentage of publications in each collaboration pattern for all three universities

Figure 7 shows the development trend of each collaboration type over the years from 1974 to 2014. From this graph, we can see that the percentage of publications with 5 authors is steadily increasing, while collaboration of 6+ authors is rapidly growing. This result validates the previous research (Liu, 2003). The percentage of publications in collaboration of 4 authors is the steadiest collaboration type across all examined years. The percentage of publications from 1 author or in collaboration with 2 authors shows the greatest decrease, while collaboration of 3 authors is gradually dropping. Also from Figure 7, 2 authors, 3 authors, and 4 authors are the most popular collaboration types from 1986 to 2013. In 2014, collaboration of 5 authors is exceeding 2 authors type. Thus, we can observe from the analysis that collaboration trends are moving from 1-3 authors towards big teams with 4 or more authors.

Average *SJR* score of publishing journals from three Australian universities

SJR score is used by Scopus to measure the impact of journals (Colledge et al., 2010). Although there are many different methods to measure the quality of scholarly journals, *SJR* score is adopted for the purpose in this research. The average *SJR* score of journals where scholars from the three representative Australian universities have published are calculated from 1974 to 2014. The average *SJR* score of publications is calculated based on total *SJR* scores of all publications versus total number of unique publications in the specific year, giving an overall measure of journal impact / quality for each university. The calculation equation for average *SJR* score of publishing journals is: $y = \frac{X_s}{X_n}$ where X_s represents total *SJR* score of publishing journals for the publications in Year X and X_n represents total number of these publications. The calculated results are distributed on a scatter plot in Figure 8.

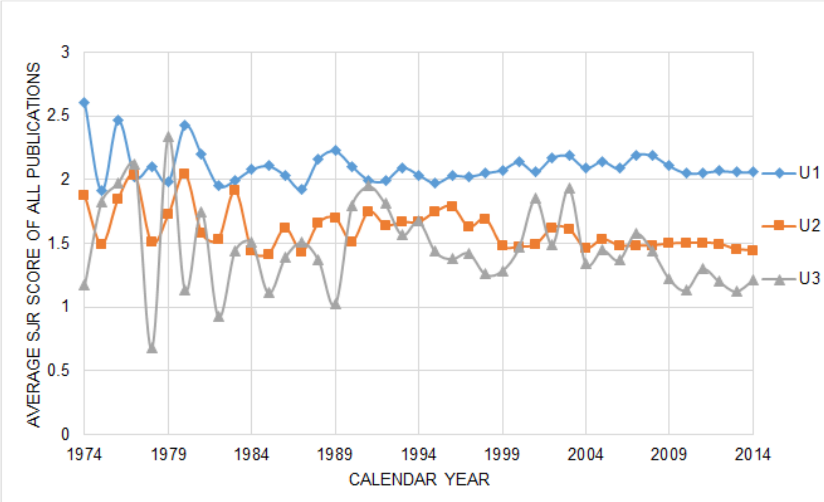

Fig. 8 Average *SJR* scores of publishing journals of three Australian universities from 1974 to 2014

From Figure 8, we observe that *U1* and *U2* deliver comparatively stable performance over the measured years. The data range of average *SJR* score for *U1* is .69, and for *U2* is .62. A relatively low number of publications, and high variability in *SJR scores* of publishing journals, gives rise to the unstable measures for *U3*, whose data range of average *SJR* score is 1.66. Across all examined years, the average *SJR* score for *U1* is 2.16, *U2* is 1.57, and *U3* is 1.36. Generally speaking, the average SJR scores for three universities appear steady over the last four decades, although the number of publications per scholar has increased, as shown in Figure 4. This would indicate that despite an apparent increase in publication output by scholars, the quality of these outputs has not changed within the Australia academic science system.

Percentage of Quartile category for three Australian universities from 1974 to 2014

The *SJR* uses Quartile to divide all *SJR* journals equally into four groups: Q1, Q2, Q3, and Q4. Each group contains 25% of all journals, with the highest ranked 25% grouped into Q1. The percentage of each Quartile category where each university has published is used to compare the publishing performance of each university. The calculation equation is: $y = \frac{X_q}{X_n}$ where X_q represents total number of publication from Quartile and X_n represents total number of unique publications from a specific university. The calculated results are shown in Figure 9.

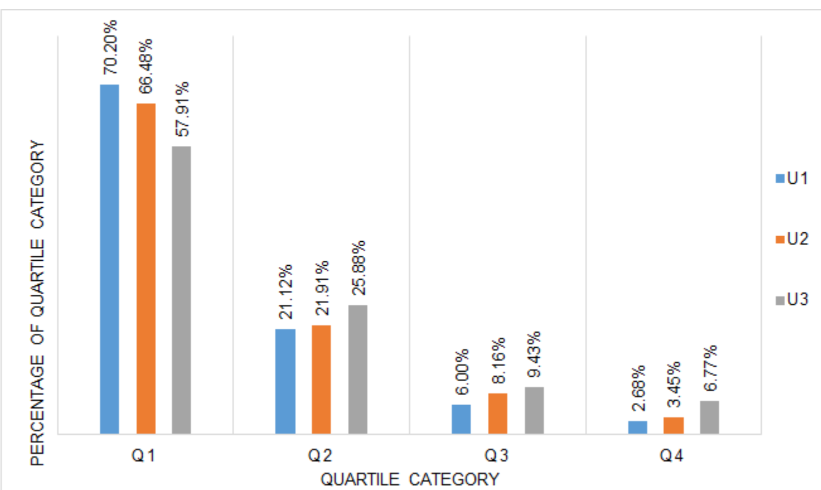

Fig. 9 Comparison of all publications by Quartile from three Australian universities from 1974 to 2014

Figure 9 reveals that all three Australian universities publish around 70% of the research results at Q1 journals, the top 25% of *SJR* journals; 21.12% - 25.88% of publications go to Q2 journals, 6% - 9.5% of publications go to Q3 journals, and only 2.68% - 6.77% of publications go to Q4 journals, the lowest 25% of *SJR* journals. Figure 9 also validates the result from average *SJR score* calculation. As indicated by the average SJR score for each university, the distribution of publications in each SJR quartiles is more heavily weighted to the low quartiles for the non-comprehensive university.

Average citation per publication from three Australian universities

Citation count measures the interest a publication has received academically through referencing, and is an indicator of the quality of the publication. The average citation per publication is calculated based on total citation of publications versus total number of unique publications in the specific year. The calculation equation for average citation per publication is: $y = \frac{X_c}{X_n}$ where X_c represents total citation of publications in Year X and X_n represents total number of these publications. The average citation per publication from three Australian universities are calculated over time from 1974 to 2014, and the calculated results are shown in Figure 10.

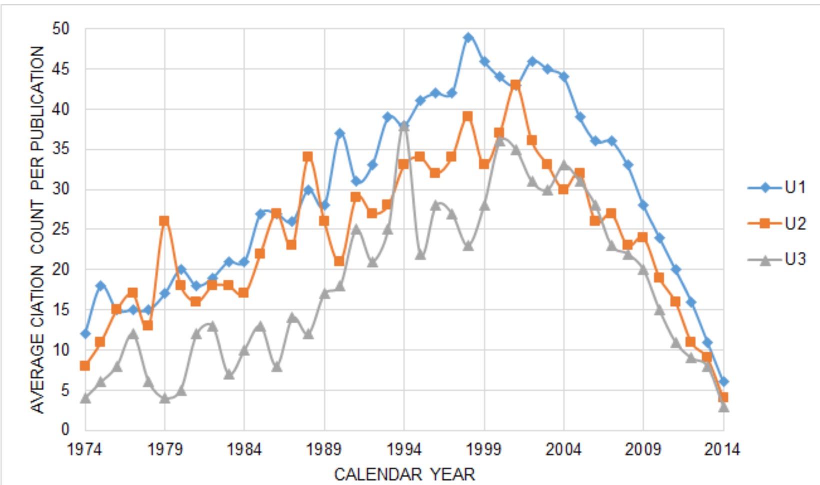

Fig. 10 Average citation per publication for three Australian universities from 1974 to 2014.

Figure 10 reveals a general increase in citations per publication, as would be expected as publications in this study age. Empirical analysis indicates that there is a delay for a journal publication to becoming broadly cited. On average, a full journal paper will have a citation peak around three years after publication (Amin & Mabe, 2004). The same rule applies to the citation life cycle for a university as a whole. From this plot covering 1974 to 2014, *U1* has a higher citation rate than *U2* except in years 1979 and 1988, and *U2* has a higher rate than *U3* except in 1994, 2004, and 2006. Figure 10 also demonstrates that the number of citations per publication goes up each year after being published, and it takes approximately 15 years for a publication to achieve peak citation rates at a university level. This delay is significantly larger than an individual journal paper, and most likely attributable to publication lag. It is also evident from Figure 10 that the average citation per publication is rapidly increasing over the period from 1974 to 2000, likely as a function of the increasing number of scholarly publications.

RQ3: How does the scholarship life-cycle vary in Australian universities in terms of publishing age?

The higher education sector has been shown to be comprised of an aging population of academic staff. The Ministry of Education of New Zealand published a 2014 report on age of the academic staff (including research only staff) at New Zealand universities in 2012 and 2013 (Education Counts, 2014). Results from this report showed overall growth in the number of academics, with an average age in 2014 of between 30 and 49. These results have also been considered in the Australian context. In 1971, academic staff in Australia were dominated by people in the 20-34 year age group, however this was found to have increased to 35-49 years in 2006 (Hugo, 2008). While the physical age of an academic is one measure of life-cycle, we provide an alternative analysis that considers an individual's publishing age, or time since their first publication. In order to determine how scholarship life-cycle structures vary across the three representative Australian universities, we investigate the academic age of scholars from three aspects: publishing age of scholars, scholarship life-cycle structure, scholarship life-cycle for active scholars and inactive scholars.

Publishing age of scholars from three Australian universities

In this research, publishing age is defined as the year difference between the first publication and the last publication for one specific scholar. The calculation equation of publishing age is $y = \frac{X_l}{X_f + 1}$ where X_l represents the year of the last publication and X_f represents the year of the first publication. The calculated results are highly skewed, especially for scholars publishing for only one year. The number of scholars with 10 or less years publishing age are listed in Table 3, together with the percentage of scholars in each publishing age category comparing to the entire scholar population in each university.

University	Publishing Age in Years									
	1	2	3	4	5	6	7	8	9	10
U1	9990 46.45%	1480 6.88%	1141 5.30%	899 4.18%	836 3.89%	695 3.23%	609 2.83%	524 2.44%	430 2.00%	389 1.81%
U2	2349 45.86%	363 7.09%	279 5.45%	207 4.04%	219 4.28%	163 3.18%	150 2.93%	115 2.25%	114 2.23%	98 1.91%
U3	627 47.21%	74 5.57%	59 4.44%	58 4.37%	50 3.77%	50 3.77%	28 2.11%	44 3.31%	34 2.56%	24 1.81%

Table 3. Number of scholars with no more than 10 years publishing age

Similar proportions of scholars with a publication age between 10 and 30 years are evident across the three universities, with 17.01% for *U1*, 17.36% for *U2*, and 17.92% for *U3*. However, the number of scholars with publishing age over 30 years from three universities appear to be interestingly different. To investigate further, the scholars with publishing age over 30 years from three universities are distributed on a line chart in Figure 11.

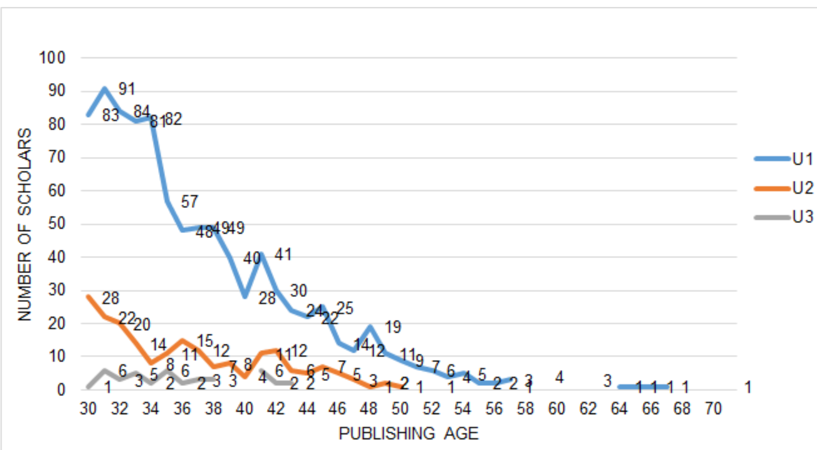

Fig. 11 Number of scholars with 30+ years publishing age from three Australian universities

The data from Figure 11 shows that a scholar from *U1* has 71-year publishing age, while the longest publishing age for *U2* is 57, and the longest publishing age for *U3* is 49. It indicates that scholars at the leading university have longer publishing age than those at the middle-tier university, and scholars at the middle-tier university have longer publishing age than those at the non-comprehensive university. This is likely a result of the different establishment dates for these representative universities, however, given the importance of longevity for citation rates, it is likely to factor into measures of impact and reputation.

Scholarship life-cycle structure at three Australian universities

To facilitate exploration of how the scholarship life-cycle impacts Australia academic science, Life-Cycle Phase (LCP) is introduced to the data analysis. A 10-year timeframe is used to differentiate LCPs. Consequently, we have five scholar groups: Age<10, 10<=Age<20, 20<=Age<30, 30 <=Age<40, and Age>=40. However, from preliminary data analysis on life-cycle and productivity, a special scholar group was identified. Within this group, scholars have a maximum three-year publishing age and can be considered as PhD candidates or new scholars. We thus classify scholars into six groups based on their publishing age: *Emerging Scholar* (Age<4), *Early Career Scholar* (4<=Age<10), *Mid-career Scholar* (10<=Age<20), *Late Mid-career Scholar* (20<=Age<30), *Senior Scholar* (30<=Age<40), *Life-time Scholar* (Age>=40).

The number of scholars within each of these groups in the three universities are extracted, and then the percentage of scholars in each LCP are calculated. The calculation equation for the percentage of scholars in Group X is $y = \frac{X_g}{X_t}$ where X_g represents total number of scholars in group X and X_t represents total number of scholars. The calculation is conducted based on each university, with results shown in Figure 12.

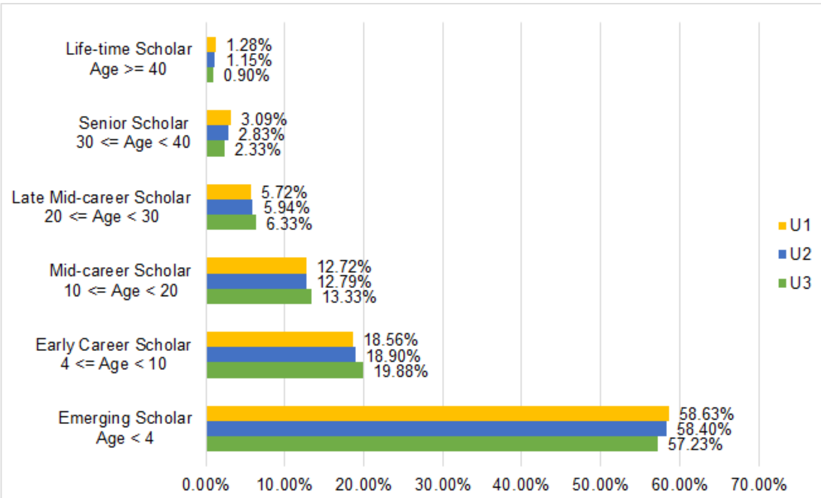

Fig. 12 Percentage of scholars in each LCP by university

We specifically consider the LCP of scholars independent of institutions. That is, the LCP analysis conducted here has no relationship to the age of the universities, and rather considers the percentage of scholars in different age phases at each university. Figure 12 reveals that each university has a similar percentage of scholars in each LCP. *Emerging Scholars* account for approximately 58% of population, *Early Career Scholars* account for approximately 19%, *Mid-career Scholars* approximately 13%, *Late Mid-career Scholars* approximately 6%, *Senior Scholars* approximately 6% population, and *Life-time Scholars* consist of only about 1% of the population. ANOVA tests were conducted and the results demonstrate that the proportion of scholars in each life cycle phase at each university are statistically significant ($p < 0.05$).

Scholarship life-cycle for *Active Scholars* and *Inactive Scholars* from three Australian universities

To better understand the changes in scholarship life-cycle structure at each of the three universities, all scholars are divided in two types: *Active Scholar* and *Inactive Scholar*. *Active Scholars* are considered to be scholars having one or more publications on or after 2012, which suggests that the scholars are still publishing. *Inactive Scholars* refer to scholars having no publications since 2011 which suggests that they have either stopped publishing, or are experiencing a break. *Active Scholar* data demonstrates the current scholarship life-cycle structure, while *Inactive Scholar* data demonstrates the past scholarship life-cycle structure. To compare these two types, the number of *Active Scholars* and the number of *Inactive Scholars* in each LCP by university are extracted, and then the percentage of each type in LCP by university is calculated. Firstly, we conducted data extraction and calculation for *Active Scholars*. The calculation equation for the percentage of *Active Scholars* in LCP X is $y = \frac{X_a}{X_t}$ where X_a represents the number of *Active Scholars* in LCP X and X_t represents the total number of *Active Scholars*, respectively for three Australian universities. The *Active Scholars* data is shown in Figure 13.

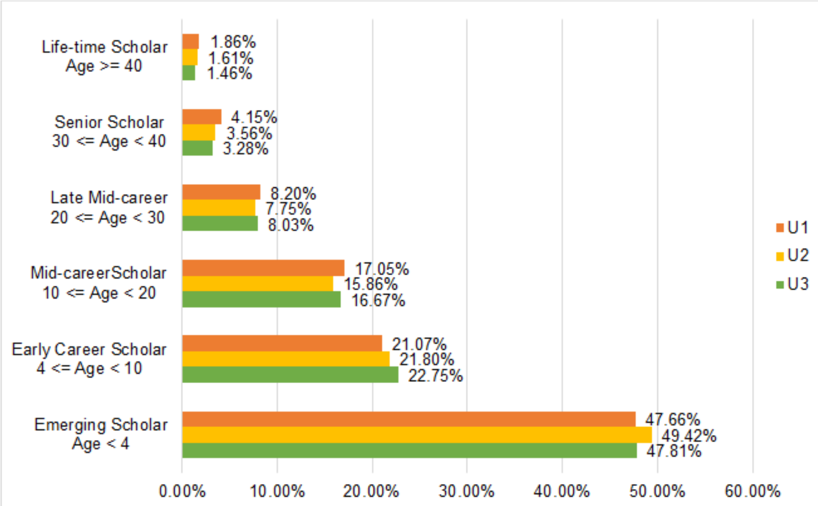

Fig. 13 Percentage of *Active Scholars* in each LCP from three Australian universities

Figure 13 reveals that *Emerging Scholars* occupy 48% - 50% of the entire *Active* population; *Early Career Scholars* occupy 21% - 23%; *Mid-career Scholars* occupy 15% - 17%; *Late Mid-career Scholars* occupy approximately 8%; *Senior Scholars* occupy only 3% - 4%; and *Life-time Scholars* occupy around 1.5% - 2%. In general, there are similar percentages of active scholars in each LCP across all three universities. *U1* has slightly higher percentage of *Active Scholars* with a more than 10-year publishing age, *U2* has higher percentage of *Emerging* Scholars, and *U3* has the highest percentage of *Early Career* Scholars of all universities.

In addition to the analysis of *Active Scholars*, we conducted data extraction and calculations for *Inactive Scholars*. Although the reasons for scholars to cease publishing are not explored in this research, the proportions of Inactive Scholars in different age groups are important for understanding the Australian academic science from a quantitative perspective as they are an important component in evaluating life-cycle factors. The calculation equation for the percentage of *Inactive Scholars* in LCP X is $y = \frac{X_i}{X_t}$ where X_i represents the number of *Inactive Scholars* in LCP X and X_t represents total number of *Inactive Scholars*, respectively for the three Australian universities. The *Inactive Scholars* data is shown in Figure 14.

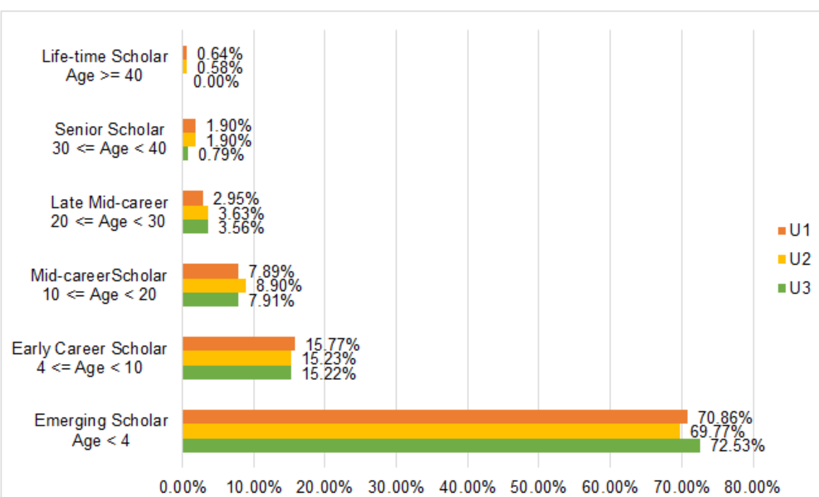

Fig. 14 Percentage of *Inactive Scholars* in each LCP from three Australian universities

Figure 14 indicates that the *Emerging Scholars* occupy around 70% of all of the *Inactive* population; *Early Career Scholars* occupy around 15%; *Mid-career Scholars* occupy around 8%; *Late Mid-career Scholars* occupy 3%; and *Senior Scholars* occupy only 1% - 2%. There is less than 1% *Life-time Scholars* in the extracted *Inactive Scholars* data. As with the previous two figures, Figure 14 also shows that all three Australian universities have a similar percentage of *Inactive Scholars* in all six LCPs, with *U1* and *U2* having a higher percentage of *Senior Scholars* and *Life-time Scholars* than *U3* in the past. U3 had higher percentage of *Emerging Scholars*, perhaps indicating a higher number of PhD candidates or early career academics.

Comparing Figure 13 and Figure 14, all three universities have a lower percentage of *Emerging Scholars*, while there are higher percentages of *Early-career Scholars*, *Mid-career Scholars*, *Late Mid-career Scholars*, *Senior Scholars*, and *Life-time Scholars* in the active group than those in the inactive group. The percentages of *Early-career Scholars*, *Mid-career Scholars*, *Late Mid-career Scholars*, and *Senior Scholars* in active scholars are higher than those for inactive. This result suggests that there is trend in scholars having longer publishing careers which is common across our three representative universities.

RQ4: What is the relationship between scholarship life-cycle and publishing performance in Australian universities?

Some of the most important scientific contributions were made early in academic careers. Gauss was 18 years old when he developed least-squares, Darwin was 29 when he developed the concept of natural selection, Einstein was 26 when he formulated the theory of relativity (Zuckerman & Merton, 1971), and Newton was 24 when he began his work on universal gravitation, calculus, and the theory of colors (Levin & Stephan, 1991). Some empirical studies show that, on average, scholars become less productive as they age (Cole, 1979; Fox, 1983; Levin & Stephan, 1991), and some show that productivities gradually increases for scholars after their PhD with age, peaking in their late 30s or early 40s, and then dropping off (Fox, 1983). In this research question, we consider the publishing performance of all three Australian universities using our previously described life-cycle phases (LCPs). We do not conduct further analysis of the performance of scholars in each LCP, as it is predictable that scholars generate more documents with time. It is also predictable that documents will receive higher citations with time. Rather, we analyze the performance of scholars in each LCP, and thus this research question targets the publishing performance in each LCP when scholars published. We also consider the publication patterns by LCP for the combined universities, rather than comparatively for each university.

The data used for this research question consists of 284,128 journal publications from the three Australian universities. All publications are categorized into six groups based on different LCP when scholars published: publications during *Emerging* phase (LCP 1), publications during *Early Career* phase (LCP 2), publications during *Mid-career* phase (LCP 3), publications during *Late Mid-career* phase (LCP 4), publications during *Senior* phase (LCP 5), and publications during *Life-time* phase (LCP 6). It means that LCP 1 contains papers published when authors had less than four years publishing age; LCP 2 contains papers published when authors had greater than or equal to four but less than 10 years publishing age; LCP 3 contains papers published when authors had greater than or equal to 10 but less than 20 years publishing age; LCP 4 contains papers published when authors had greater than or equal to 20 but less than 30 years publishing age; LCP 5 contains papers published when authors had greater than or equal to 30 but less than 40 years publishing age; and LCP 6 contains papers published when authors had greater or equal to 40 years publishing age. For example, a mid-career scholar has his/her publications distributed in three phases: LCP 1, LCP 2, and LCP 3; and a senior scholar has his/her publications distributed in five phases: LCP 1, LCP 2, LCP 3, LCP 4, and LCP 5. The analysis of publications in each phase are considered from the following aspects: number of documents, percentage of first-author publications, collaboration pattern, *SJR* score of publishing journals, Quartile category of publishing journals, citation analysis.

Number of documents

In the first instance, all of the publications are extracted and classified based on the scholarship life-cycle into six phases. There are in total 284,128 publications, and the percentage for each period in all publications is calculated. The extract and calculation results are shown in Figure 15.

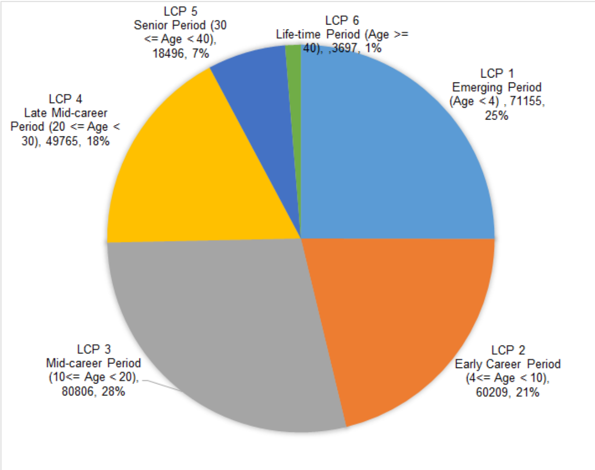

Fig. 15 Number of publications in each LCP

From this chart, we see that LCP 1, LCP 2, and LCP 3 deliver a combined 74.7% of all publications, while LCP 3 delivers the highest number of publications individually. Less publications are generated when publishing age reaches *Late Mid-career* phase due to fewer academics, and this continues with publishing time.

Percentage of first-authored publications

The first-authored publications from each LCP are extracted, and the percentage of first-authored publications in each phase is calculated. The calculation equation for the percentage of first-authored publications is $y = \frac{X_f}{X_t}$ where X_f represents the number of first-authored publications in phase X and X_t represents the total number of publications in phase X. The calculated results are shown in Figure 16.

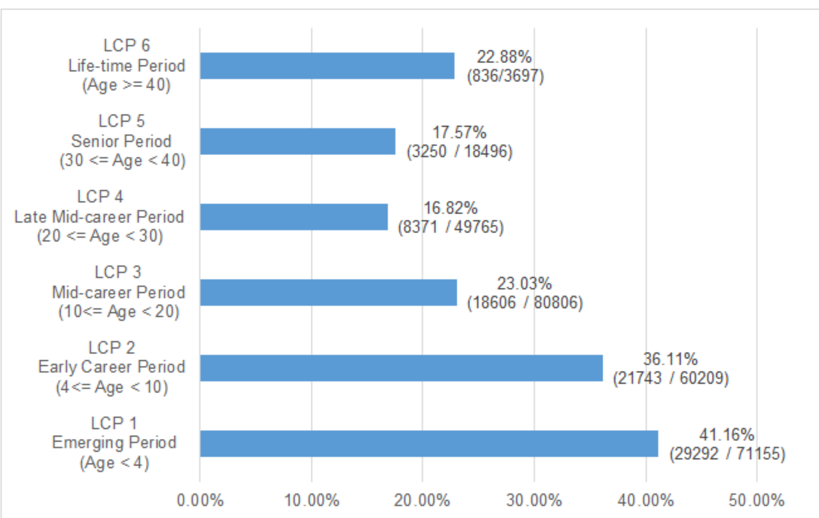

Fig. 16 First-authored publications in each LCP

Figure 16 shows an interesting phenomenon, with scholars publishing fewer first-authored papers as their publishing ages grow, until they reach senior scholar phase. It also shows that scholars tend to publish slightly more first-authored papers when they reach 30-year publishing age at LCP 5 and LCP 6.

Collaboration pattern

More experienced scholars tend to publish fewer first-authored publications, perhaps aligning to their transition to more supervisory roles. This sub-section explores the collaboration pattern of scholars in each LCP. The publications with 1 author, 2 authors, 3 authors, 4 authors, 5 authors, and 6+ authors from each LCP are extracted, and the percentage of publications by different collaboration pattern in each LCP is calculated. The calculation equation for the percentage of phase X publication by a specific collaboration pattern is $y = \frac{X_n}{X_t}$ where X_n represents the number of publications in phase X by a specific collaboration pattern and X_t represents the total number of publications by the same collaboration pattern. The collaboration patterns for each LCP are shown in Figure 17.

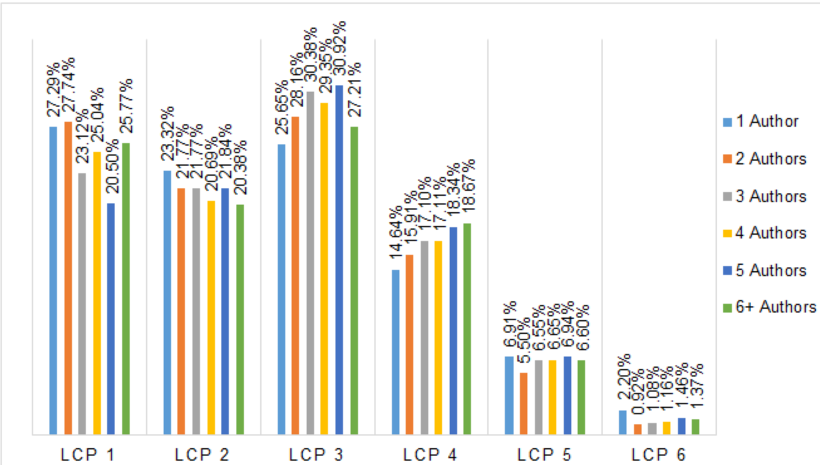

Fig. 17 Comparison of collaboration patterns in different LCP

Figure 17 demonstrates scholars tend to work with one or two scholars during their *Emerging* phase and *Early Career* phase, as shown in LCP 1 and LCP 2, and scholars tend to work in larger teams during *Mid-career* phase and *Late-mid Career* phase, as shown in LCP 3 and LCP 4. Scholars in LCP 5 and LCP 6 have slightly higher percentage of sole authorships, otherwise they distribute their publications almost equally in the remaining five collaboration patterns.

***SJR* score of publishing journals**

To measure the performance of each LCP, *SJR* scores of all journals from the publications in each LCP is summed, and then the average *SJR* score of publishing journals is calculated. The calculation equation for the average *SJR* score of publishing journals in phase X is $y = \frac{X_{sjr}}{X_t}$ where X_{sjr} is the total *SJR* scores of publishing journals in phase X and X_t is the total number of publications in phase X. The calculated results are shown in Figure 18.

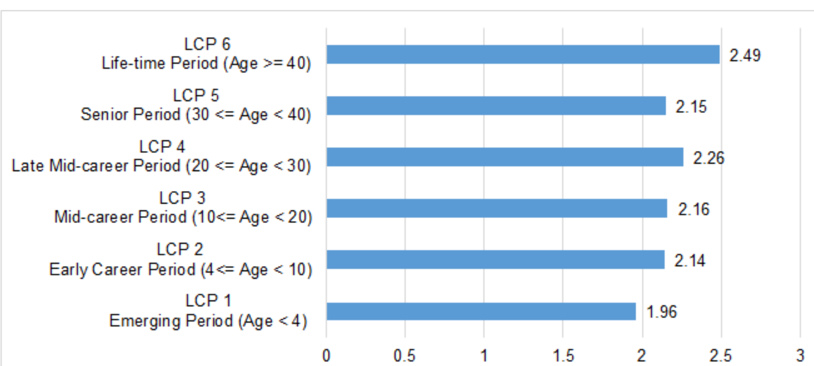

Fig. 18 Average SJR score of publishing journals per publication in each LCP

Expectedly, Figure 18 shows that scholars during *Emerging* phase on average publish at lowest ranked journals, and scholars during *Life-time* phase publish at the highest ranked journals. Scholars during *Early Career* phase publish at higher scored journals than at *Emerging* Phase, and performance stays almost the same for *Early Career* phase, *Mid-career* phase, *Late Mid-career* phase, and *Senior* phase.

Quartile category of publishing journals

All *SJR* journals are equally divided into four Quartiles: Q1, Q2, Q3, and Q4. The publications in different Quartiles are extracted based on each LCP. And then the percentage of Quartile publications in each phase is calculated. The calculation equation for the percentage of specific Quartile publications in phase X is $y = \frac{X_q}{X_t}$ where X_q is the number of publications listed in the specific Quartile in phase X and X_t is the total number of publications in phase X. The calculated results are shown in Figure 19.

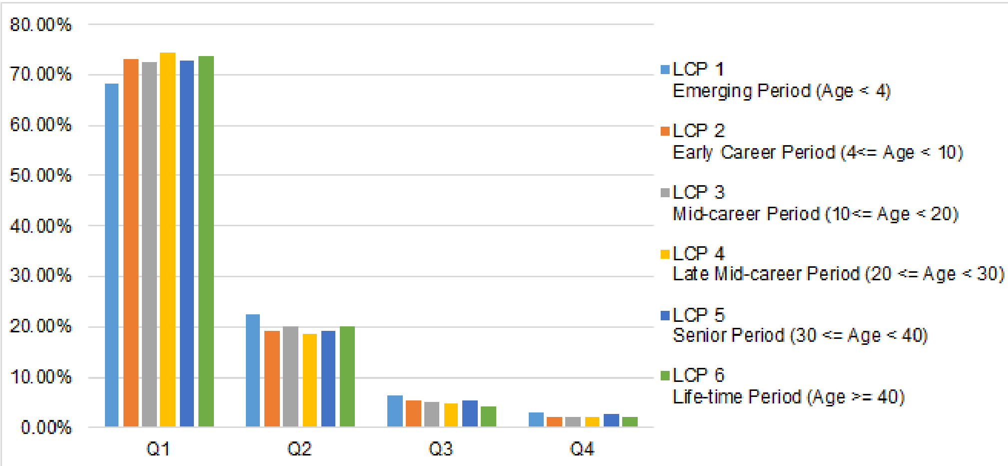

Fig. 19 Comparison of Quartile category of publishing journals in different LCP

From Figure 19 we can see that scholars at *Emerging* phase publish at lower ranked journals compared to all other phases, and scholars at *Life-time* phase publish at higher ranked journals comparing to other LCPs. The majority of the publications from three Australian universities listed in Scopus are published in Q1 journals. To validate the difference, an ANOVA test was conducted between every two Quartiles and the results show that the number of publications from four Quartiles from six LCPs is statistically significantly different ($p < 0.05$).

Citation analysis

To measure the scholarly performance of each LCP, citation analysis is adopted. Each publication has a citation, and there are in total 284,128 publications. Average citation per publication is calculated to measure each LCP. The calculation equation for the average citation per publication in phase X is $y = \frac{X_c}{X_t}$ where X_c is the total citation of all publications in phase X and X_t is the total number of publications in phase X. The calculation results are listed in Table 4.

Life-Cycle Phase	Number of Publications	Average Citation per Publication
LCP 1	71,155	22.08
LCP 2	60,209	26.44
LCP 3	80,806	27.39
LCP 4	49,765	27.49
LCP 5	18,496	24.26
LCP 6	3,697	21.26

Table 4. Average citation per publication in each LCP

Table 4 shows that scholars in their *Mid-career* phase and *Late-mid Career* phase deliver publications which attract the highest citation. The publications during *Emerging* phase and *Life-time* phase attract the lowest citation, however, this is likely impacted by citation latency.

Conclusion

In this paper, we have presented the results of analysis of scholars and their publication data over the period from 1974 to 2014 for three different Australian universities. From this analysis, we sought to answer research questions related to the growth of publications and scholars from Australia, the differences among scholarly publications from different university types, the scholarship life-cycle structure in Australia universities, and the differences among scholarly publications in different life-cycle phases. A number of interesting patterns emerge from the results presented in this study.

Firstly, the growth rate of all academic publications in Australia is approximately 6.8% from 1974 to 2014, while the expected growth rates of journal publications for our three profiled universities are 6.72% for the leading university, 7.37% for the middle-tier university, and 9.68% for the non-comprehensive university. This indicates potential greater growth opportunity for less established, lower ranked universities. This may be due to smaller size and less comprehensive profiles creating greater opportunity adaptive capacity, or market forces driving more competitive behaviour. Similarly, the growth rates of new scholars are 5.16% for the leading university, 5.94% for the middle-tier university, and 6.83% for the non-comprehensive university. Although we see slight differences in the growth rates of new scholars, the overall growth of scholars at three Australian universities is 4.5%.

Secondly, the average number of publications per scholar from 1974 to 2014 steadily increased across the profiled universities with time, with U1 having the highest productivity per scholar, followed by U2 then U3. However, the differences in the observed productivity per scholar across the three universities are very minor in the most recent six years. From visual observation of the publication outputs from the three universities considered in this study, an increase in the average number of publications per scholar commenced in the mid 1980s, grew steadily through the 1990s, and increased dramatically at the end of the 2000s. This result is a likely indicator that Australian institutional research policies implemented during the late 1980s, and government funding policies from 1990s, have had an impact on the publication output of scholars (Butler, 2003a, 2003b). It is also suggestive that the introduction of global university ranking schemes in 2003 has further fueled this trend (Marginson & Van der Wende, 2007; Sullivan, 1996). The percentage of first-authored publications from 1974 to 2014 for the leading university is 42%, 45.6% for the middle-tier university, 50.3% for the non-comprehensive university. The empirical evidence shows that a team of two or three scholars was the most popular collaboration pattern across 40 years. However, in the last four years, a team of three or four authors has become the most popular collaboration type, with collaboration in larger teams becoming more important for scholarly research work.

Our results support previous research linking increased collaboration patterns with increased publication output (Haslam et al., 2016). Thus the identification of higher rated collaboration in larger research teams is encouraged by the higher number of publications, which is another likely impact of institutional and governmental research policies introduced to Australia (Butler, 2003a, 2003b). This research also illustrates that academics within higher-ranked universities tend to engage more in team collaboration, while lower-ranked universities tend to work alone or with another scholar. All three Australian universities publish around 70% of the research results at Q1 journals, the top 25% of SJR journals. Furthermore, the average *SJR* score per publication for the leading university is 2.16, the middle-tier university is 1.57, and the non-comprehensive university is 1.36, indicating a difference in quality outcomes. The average SJR scores for three universities have been maintained steady in the last four decades, although the number of publications per scholar increased. This shows that the quality of publications didn't drop although the quantity of publications increased. In terms of publication impact, the higher-ranked universities in this study had a higher citation count per publication. Our study indicates that the number of citations per publication goes up each year from being published, taking approximately 13-16 years for a publication to reach its peak citation rate.

Thirdly, in this research, scholarship life-cycle classifies scholars into six groups based on their publishing age: *Emerging Scholar* (Age<4), *Early Career Scholar* (4<=Age<10), *Mid-career Scholar* (10<=Age<20), *Late Mid-career Scholar* (20<=Age<30), *Senior Scholar* (30<=Age<40), *Life-time Scholar* (Age>=40). Each university we considered has a similar percentage of scholars in each LCP. *Emerging Scholars* account for approximately 58% of population, *Early Career Scholars* approximately 19%, *Mid-career Scholars* approximately 13%, *Late Mid-career Scholars* approximately 6%, *Senior Scholars* approximately 6% population, and *Life-time Scholars* contain only about 1% population. There is also a trend in scholars having longer publishing age. Our research data shows that the longest publishing age is 71 years for the leading university, 57 years for the middle-tier university, and 49 years for the non-comprehensive university; overall, scholars at the higher-ranked universities have longer publishing age years than those at the lower-ranked university.

Lastly, all publications from this study were categorized into six groups based on the life-cycle phase of when scholars published: publications during *Emerging* phase (LCP 1), publications during *Early Career* phase (LCP 2), publications during *Mid-career* phase (LCP 3), publications during *Late Mid-career* phase (LCP 4), publications during *Senior* phase (LCP 5), and publications during *Life-time* phase (LCP 6). The research results show that LCP 1, LCP 2, and LCP 3 deliver more than 20% of all publications, while LCP 3 delivers over 28% of publications; the highest yield for scholars. Fewer publications are generated when publishing age reaches *Late Mid-career* phase. An interesting but expected phenomenon, that scholars publish less first-authored papers than in their *Emerging* phase as their publishing age grows until they reach senior scholar phase, was confirmed. *Senior scholars* and *Life-time scholars* tend to publish slightly more first-authored papers. Scholars tend to work with one or two scholars during their *Emerging* phase and *Early Career* phase, and scholars tend to work with more than two scholars during *Mid-career* phase and *Late-mid Career* phase with scholars in LCP 5 and LCP 6 have slightly higher percentage of sole-authorships. Scholars during *Early Career* phase publish at higher ranked journals than at *Emerging* phase, and performance stays almost the same for *Early Career* phase, *Mid-career* phase, *Late Mid-career* phase, and *Senior* phase. Scholars at the *Emerging* phase publish at lower ranked journals compared to all other phases, and scholars at *Life-time* phase publish at higher ranked journals. *Mid-career* phase and *Late-mid Career* phase deliver the best quality publications which attract the highest number of citations. The publications during *Emerging* phase and *Life-time* phase attract the lowest citations.

This research aims to evaluate relationships among scholarly publications, and scholars at universities in Australia. Due to the amount of academic publication data available, we selected three Australian universities representative of the key university types of *leading university*, *middle-tier university*, and *non-comprehensive university* in Australia. Thus, the number of scholarly publications considered in this study is limited to 284,128. This is a sufficient data size to represent Australian academic science for this research study, however, it does not contain all publications from all Australian universities.

Additionally, it is worth mentioning that this research uses scholarship life-cycle to study the relationships among scholarly publications, scholars, and universities. Scholarship life-cycle is an important characteristic of scholars. Yet, this is not the only one. Scholars consist of many characteristics, such as publication productivity, research output weight, and so on. This requires a more comprehensive typology development for scholars, which will be the subject of future work. This will allow the quantitative relationships between scholars and publications, and between scholars and universities, to be conducted through additional characteristics of scholars. Additionally, future work that considers discipline specific differences in scholarly publication would also be useful. While interesting discipline based differences have been observed in citation rates (Harzing & Alakangas, 2016), further analysis of the possible effect of discipline differences in publication outputs, co-authorship within and beyond the same university, and life cycle patterns is warranted. Also, a country based comparison of the citation analysis may yield interesting results. Notwithstanding these limitations, the work presented in this paper makes an important contribution to the understanding of performance differences across institutions in the higher education sector.

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