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Tracking research performance before and after receiving the Cheung Kong Scholars award: A case study of recipients in 2005

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Abstract

The Cheung Kong Scholars Program has become a nationally important, high-level talent plan. In this study, we determined whether the research output and coauthorship pattern of Cheung Kong Scholars changed after their receipt of the award. We selected the 83 recipients of the 2005 Cheung Kong Scholars Award and identified a total of 11,522 Science/Social Sciences Citation Index papers published between 1996 and 2015 by these awardees. The analysis was divided into two 10-year periods—the preaward (1996–2005) and postaward (2006–15) periods—to investigate changes in the scholars' research performance. The results revealed that the number of papers authored by each Cheung Kong Scholar increased significantly, and there were also significant increases between the two periods in terms of average citation count and journal impact factor, suggesting that the quality of the scholars' papers improved in tandem with the quantity. Second, a quadrant chart revealed that individuals exhibited different trends in productivity and impact, but their impacts' distribution in the postaward period was much more concentrated than that in the preaward period. Third, the scholars' coauthorship patterns changed significantly after receiving the award—not only their number of coauthors per paper significantly increased but also their authorship role changed significantly. In both number and proportion, they became less likely to act as the first author, but more likely to be listed as the last author. Furthermore, they published more papers as corresponding author, and more papers as the first, corresponding, or last author, though their proportion did not change significantly.

Key words: Cheung Kong Scholars; bibliometrics; number of papers; citation; coauthorship pattern

1 Introduction

Over the years, China has recruited many young domestic and international scholars to build up key academic disciplines at Chinese colleges and universities, thereby revitalizing China's higher education system and its academic position in the world. As part of this process, the Cheung Kong Scholars Program was jointly established in 1998 by the Ministry of Education of the People's Republic of China and the Li Ka Shing Foundation in Hong Kong to help key disciplines pursue or maintain an international standard of advancement and cultivate a new group of leading international scholars. Colleges and universities in China are permitted to recruit approximately 150 distinguished professors (increased from 100 to 150 since 2011) and 50 lecturing professors (decreased from 100 to 50 since 2011) from home and abroad annually. For each post, the college or university should establish a peer review committee to review all the applicants in strict accordance with the requirements. The candidates who pass the first review are then submitted to the Ministry of Education of the People's Republic of China. Subsequently, candidates must pass the communication review, conference review, public notice, and review committee of the Cheung Kong Scholars Program. To be eligible, scholars must have demonstrated impressive research capabilities and received recognition

from their peers; generally, they should also have a doctorate. In principle, natural science scholars should not be more than 45 years old, and humanities and social sciences scholars should not be over 55 years (increased from 50 to 55 years since 2011). However, for those who are particularly prominent or unique, the age requirements can be appropriately relaxed. Foreign applicants must generally be serving in high-level universities as assistant professors or in more senior posts, whereas domestic applicants should be serving as professors or in corresponding positions. Selected distinguished professors receive an allowance of 200,000 yuan per year (increased from 100,000 to 200,000 yuan since 2011) during their 5-year appointment (changed from 3 years to 5 years since 2011), in addition to a salary, insurance, welfare, and other benefits (The Ministry of Education of the People's Republic of China 2005). As of the announcement of the list of Cheung Kong Scholars in 2016, the award has been issued to a total of 2,144 distinguished professors and 897 lecturing professors (just need to do some lectures at universities during their 3-year appointment) over the years.

With the current international competition for human resources, talent recruitment has become a national strategy (Wang 2014). Cheung Kong Scholars are an important proportion of the high-level talent in colleges and universities, and they shoulder the major responsibility of training young people in creative thinking and conducting independent research. With the support and encouragement of the Cheung Kong Scholars Program, a group of scholars has become the leaders in their fields. According to reports, by the end of April 2014, 108 Cheung Kong Scholars had been elected to the Chinese Academy of Sciences or Chinese Academy of Engineering, and 14 had been elected to the Third World Academy of Sciences. More than 400 scientific studies by Cheung Kong Scholars have won China's three major scientific and technological awards. Some Cheung Kong Scholars have also won international awards, including the 'International Award for Quantum Molecular Science' and 'Third World Academy of Sciences Award'. Cheung Kong Scholars have collectively published hundreds of papers in international academic journals such as *Nature* and *Science*.

The Cheung Kong Scholars Program has been highly praised by researchers. According to news reports, the Nobel Prize winner in physics Dr. Chen Ning Yang (also known as Zhenning Yang) believes the program to be an extraordinary feat that is 'invigorating the country [China] through science and education'. Dr Ray J. Wu, a famous molecular biologist and foreign academician of the Chinese Academy of Engineering, has stated that the program could play a crucial role in promoting China and enabling it to catch up with the world in many fields. Many university presidents have commented on the plan as setting up a new model for the use of talent; the talent plan combines the election, attraction, reward, and support of talent (Sina News 2005).

Some researchers, however, have argued that there are problems in the implementation of talent programs such as the Cheung Kong Scholars Program. These talent programs, they argue, are closed systems that create a concentration of scientific and technological resources, professional titles, and awards. Some researchers have chosen to concentrate on increasing their quantity of papers and following the research hotspot blindly instead of pursuing scientific excellence, which makes the academic circle increasingly utilitarian. Moreover, a chain has formed between the various talent programs, such that receiving awards increases the likelihood of further program opportunities. Many incentive programs have problems such as nonconformance to scientific standards, biased selection

processes, and flawed management. To some extent, these problems disrupt the norms of scientific research and encourage the formation of academic bubbles.

The main purpose of the Cheung Kong Scholars Program is to attract young researchers from home and overseas, to bring Chinese research in key disciplines up to the level of international research, and to train new international academic leaders. Very few studies have examined the Cheung Kong Scholars Program; those that have investigated it have mainly focused on the scholars' demographic characteristics, rather than changes in their research output or authorship patterns after receipt of the award. To address this gap in the literature, the present study asks the following questions: Have the Cheung Kong Scholars fulfilled the goals of the award? How has their research performance changed, if at all?

Studies about Cheung Kong Scholars have explored the distributions of gender, region of origin, discipline, education, and other demographic aspects. Using information from recipients' résumés, Niu and Zhou (2012) analyzed China's major high-level scientific and technological personnel plans, including the Cheung Kong Scholars Program, by gender, age, geographical location, and career status. They discovered that there were fewer women and fewer young researchers among the funded scholars; most scholars came from the Zhejiang or Jiangsu provinces; most awardees had studied in the USA, Japan, Germany, or the UK; and there was a strong Matthew effect. Zhang and Li (2014) analyzed the employed university, nationality, age, and other characteristics of 90 physics Cheung Kong Scholars. Their results indicated that the employment of China's physics scholars is overcentralized to a few prestigious colleges and universities and that there is an 'inbreeding coefficient' between the universities from which the scholars' obtained their degrees and those from which they received their faculty positions. In addition to the basic characteristics of gender, age, education, and position, Gao (2014) examined changes in institution and job title and other major events during the long careers of Cheung Kong Scholars.

Some studies have focused on other talent improving programs, awards, or grants in addition to the Cheung Kong Scholars Program. These studies have investigated the impact of these programs on the careers of awardees. Chan, Gleeson and Torgler (2014) calculated the number of awards received by Nobel Prize winners both before and after winning the Nobel Prize. The study found that the scholars' rate of award increased before receiving the Nobel Prize, but afterward there was a sharp downward trend. Bloch, Graversen and Pedersen (2014) found that research grants had a positive impact on academic performance and career advancement; scholars who received funding were twice as likely to be promoted to professors as those who did not receive funding. The study also used semistructured interviews with successful applicants to qualitatively discuss the effect of grants on career development, scientific research, teaching, and cooperation. Neufeld (2016) used logical regression and linear regression of aspects such as number of papers, citations, and journal impact factor (JIF) to analyze the relationship between a scholar's 'past performance', 'funding decisions', and 'subsequent performance'. Godin (2003) analyzed the impact of research grants from Natural Science and Engineering Research Council of Canada (NSERC) on the productivity and quality of scientific research. He chose 15,000 researchers who received funding between 1990 and 1999 and analyzed the proportion of Canadian papers that were written by funded researchers and how the proportion changed over the subsequent decade. Benoit Godin also analyzed the proportion of coauthored papers published by the funded researchers and the impact factor of the journals in which funded researchers' papers appeared. To determine the impact of NSERC's Research Grants

Program, Benoit Godin analyzed the quantity and quality of the funded researchers' papers as a function of the dollar amount of the grants they had received, and compared the work of established researchers (researchers who had received funding regularly for 10 years) with that of new researchers who had just come into the system and those who had never received any grants.

Coauthorship patterns are also considered a critical topic in research on the effects of funding programs, grants, or awards. For example, using the publication records of 198 Nobel laureates, Chan, Onder and Torgler (2015) investigated whether Nobel laureates' collaborative activities decreased after receipt of the prize. Overall, their results indicated that the recipients tended to collaborate less with new coauthors after receiving the award, but that they are more loyal to the collaborations that had started before receiving the prize, suggesting that Nobel laureates tend to collaborate more with their old coauthors. In a study of authorship patterns in the field of information systems, Cunningham and Dillon (1997) compared the collaboration patterns of researchers of different genders. They discovered that female authors were more likely to collaborate than male authors. In the medical field, numerous studies have shown a proliferation in the number of authors of published studies with time goes by (Levsky et al. 2007; Papatheodorou, Trikalinos and Ioannidis 2008; Camp and Escott 2013), a decrease in single-author publications (Modi et al. 2008; Dotson et al. 2011; Pinter 2015), and a rise in the number of international contributions (Reich et al. 2014; Cvetanovich et al. 2015; Schrock, Kraeutler and McCarty 2016). Lehman et al. (2017) analyzed authorship trends in the *Journal of Arthroplasty* over 30 years. They found a significant increase in the number of authors per publication, rising from 3.45 authors in 1986 to 4.98 authors in 2015; a significant increase in the proportion of first authors with a bachelor's degree, MD/PhD, and MD/MBA; a significant decrease in first authors with only an MD degree; and a significant increase in the number of last authors with an MD/PhD and MD/MBA.

The main objective of this study was to compare the research output and coauthorship patterns of Cheung Kong Scholars in the 10 years before and 10 years after their receipt of the award. The four specific aims of this study were as follows:

1. To determine whether there are significant differences in the research output of Cheung Kong Scholars over time, as measured by number of papers, average citation counts per paper, and JIFs.
2. To analyze changes in individuals' productivity and research impact compared with the median level.
3. To identify any significant differences in the coauthorship patterns of Cheung Kong Scholars before and after receipt of the award.
4. To suggest possible explanations for these changes and ways of improving China's talent development programs.

The rest of this article is organized as follows: the second part is data set and methodology; then, we present our research findings; and finally, we discuss the results and conclusions of the study.

2 Data and methodology

2.1 Data collection

The Cheung Kong Scholars Program was established to enhance the international visibility and status of China's research in key disciplines. Activities such as attending international conferences, holding important positions on international academic committees, and publishing high-quality papers may be considered indicators of how active a country's researchers are on the international scene. Among these activities, publication of Science/Social Sciences Citation Index (SCI/SSCI) papers is one of the most direct, crucial, and easily quantifiable measures.

For this study, we collected the demographic and background characteristics of distinguished professors who received the Cheung Kong Scholars Award in 2005, including their name, gender, year of birth, PhD information, affiliation, position, and research field. Next, we retrieved their SCI/SSCI papers published between 1996 and 2015 from the Web of Science using queries based on the combination of author name and affiliations. The downloaded records included the bibliographic information of each paper, such as its accession number, title, author, first author, corresponding author, last author, journal, JIF, key words, times cited, publishing year, subject, and research field. To account for variety in English-language spellings of Chinese names and disambiguate the works of authors with similar names, we manually checked the results to determine the final data set. Considerable time and effort were spent on data preprocessing to ensure the integrity and correctness of the data set.

After processing, our data set held the demographic and background information of 83 scholars and records of 11,522 papers (2,515 published preaward and 9,007 postaward). Although there were 102 distinguished professors in the 2005 Cheung Kong Scholars Program, we focused on those in the fields of medicine (11, 13%), engineering (41, 49%), the natural sciences (28, 34%) and the agricultural sciences (3, 4%). There were 79 men and 4 women. Only one scholar did not have a doctorate; the others obtained their PhD at a median age of 31 years (ranging from 23 to 45 years). Among them, 36 (43%) received their PhD overseas. Table 1 lists the distribution of awardees' age at award win and the outcome variables. The average and median age at award win were both 42 years, with an SD of 3.5 years (5 scholars of age 31–35, 19 scholars of age 36–40, 50 scholars of age 41–45, and 9 scholars of age 46–49 years) and an aforementioned age limit of 45 years for natural science scholars and 50 years for humanities and social science scholars. The average number of papers per scholar and citations per paper in the two time periods is also provided in Table 1.

2.2 Methodology

The data set of this study comprised 83 researchers and 11,522 papers. The analysis was divided into two 10-year periods—the preaward period (1996–2005) and the postaward period (2006–15). The following indicators were calculated for each individual to measure their research output and coauthorship patterns in each period:

1. P_{pre} and P_{post}

$$P_{pre} = \sum_{i=1996}^{2005} P_i \qquad P_{post} = \sum_{i=2006}^{2015} P_i \qquad \text{Equation (1)}$$

where P_{pre} and P_{post} represent the total numbers of papers published by the scholar between 1996 and 2005 and between 2006 and 2015, respectively, and P_i represents the number of papers published by the scholar in the year i.

Table 1. Distribution of age and outcome variables ($N = 83$)

Variables	Mean	SD
Award-winning age	42	3.5
Papers per scholars		
Published in the preaward	30	23.55
Published in the postward	108	86.79
Citations per paper		
Published and cited in the preaward	11.38	36.42
Published and cited in the postaward	14.47	20.20

2. C_{pre} and C_{post}

$$C_{pre} = \sum_{i=1}^{P_{pre}} \sum_{j=1996}^{2005} C_{ij} \qquad C_{post} = \sum_{i=1}^{P_{post}} \sum_{j=2006}^{2015} C_{ij} \qquad \text{Equation (2)}$$

where C_{pre} and C_{post} represent the total citation counts for the scholar between 1996 and 2005 and between 2006 and 2015, respectively, and C_{ij} represents paper i's citation counts received in the year j.

3. CPP_{pre} and CPP_{post}

$$CPP_{pre} = \frac{C_{pre}}{P_{pre}} \qquad CPP_{post} = \frac{C_{post}}{P_{post}} \qquad \text{Equation (3)}$$

where CPP_{pre} and CPP_{post} represent the scholar's average citation counts per paper published and cited between 1996 and 2005 and between 2006 and 2015, respectively.

4. IF_{pre} and IF_{post}

$$IF_{pre} = \frac{\sum_{i=1}^{P_{pre}} IF_i}{P_{pre}} \qquad IF_{post} = \frac{\sum_{i=1}^{P_{post}} IF_i}{P_{post}} \qquad \text{Equation (4)}$$

where IF_{pre} and IF_{post} represent the scholar's average JIF per paper published between 1996 and 2005 and between 2006 and 2015, respectively, and IF_i represents paper i's JIF.
In this analysis, we used the JIF for that paper's publication year as the paper's JIF. If there was no JIF in that year, we employed the JIF for the next year in which it was provided. There were 72 papers that have no JIF because they were published in journals that were not indexed by *Journal Citation Reports*. Because these papers accounted for only 0.6% of the total, we decided to remove them from the JIF analysis.

5. NP_{pre} and NP_{post}

$$NP_{pre} = \frac{P_{pre}}{median_{i=1\ldots83}\left(P_{pre}\right)} \qquad NP_{post} = \frac{P_{post}}{median_{i=1\ldots83}\left(P_{post}\right)}$$
$$\text{Equation (5)}$$

where NP_{pre} and NP_{post} represent the scholar's publication counts normalized by the median publication count of the 83 awarded researchers in the preaward period and postaward period, respectively. Every scholar's NP_{pre} and NP_{post} was greater than 0. A value greater than 1 indicated that the scholar's paper count was higher than the median for the total period; a value lower than 1 indicated that the scholar's paper count was lower than the median.

6. $NCPP_{pre}$ and $NCPP_{post}$

$$NCPP_{pre} = \frac{CPP_{pre}}{median_{i=1\ldots83}\left(CPP_{pre}\right)}$$
$$\text{Equation (6)}$$
$$NCPP_{post} = \frac{CPP_{post}}{median_{i=1\ldots83}\left(CPP_{post}\right)}$$

where $NCCP_{pre}$ and $NCCP_{post}$ represent the scholar's average citations per paper normalized by the median of average citations per

paper of the 83 awarded researchers in the preaward period and postaward period, respectively. Similar to NP_{pre} and NP_{post}, when the values of $NCCP_{pre}$ and $NCCP_{post}$ were greater than 1, the scholar's average number of citations per paper was higher than median level.

7. A_{pre} and A_{post}

$$A_{pre} = \frac{\sum_{i=1}^{P_{pre}} A_i}{P_{pre}} \qquad A_{post} = \frac{\sum_{i=1}^{P_{post}} A_i}{P_{post}} \qquad \text{Equation (7)}$$

where A_{pre} and A_{post} represent the scholar's average numbers of coauthors per paper published between 1996 and 2005 and between 2006 and 2015, respectively, and A_i represents paper i's number of authors.

8. $\#FA_{pre}$ and $\#FA_{post}$

$$\#FA_{pre} = \sum_{i=1996}^{2005} FA_i \qquad \#FA_{post} = \sum_{i=2006}^{2015} FA_i \qquad \text{Equation (8)}$$

where $\#FA_{pre}$ and $\#FA_{post}$ represent the numbers of papers for which the scholar was the first author between 1996 and 2005 and between 2006 and 2015, respectively, and FA_i represents the number of papers for which the scholar was the first author in year i.

9. $\#CA_{pre}$ and $\#CA_{post}$

$$\#CA_{pre} = \sum_{i=1996}^{2005} CA_i \qquad \#CA_{post} = \sum_{i=2006}^{2015} CA_i \qquad \text{Equation (9)}$$

where $\#CA_{pre}$ and $\#CA_{post}$ represent the numbers of papers for which the scholar was the corresponding author between 1996 and 2005 and between 2006 and 2015, respectively, and CA_i represents the number of papers for which the scholar was the corresponding author in year i.

10. $\#LA_{pre}$ and $\#LA_{post}$

$$\#LA_{pre} = \sum_{i=1996}^{2005} LA_i \qquad \#LA_{post} = \sum_{i=2006}^{2015} LA_i \qquad \text{Equation (10)}$$

where $\#LA_{pre}$ and $\#LA_{post}$ represent the numbers of papers for which the scholar was the last author between 1996 and 2005 and between 2006 and 2015, respectively, and LA_i represents number of papers for which the scholar was the last author in year i. If the scholar is listed as both the corresponding author and the last author, the paper was included in the corresponding author list, not in the last author list.

11. $\#FCLA_{pre}$ and $\#FCLA_{post}$

$$\#FCLA_{pre} = \sum_{i=1996}^{2005} FCLA_i \qquad \#FCLA_{post} = \sum_{i=2006}^{2015} FCLA_i$$
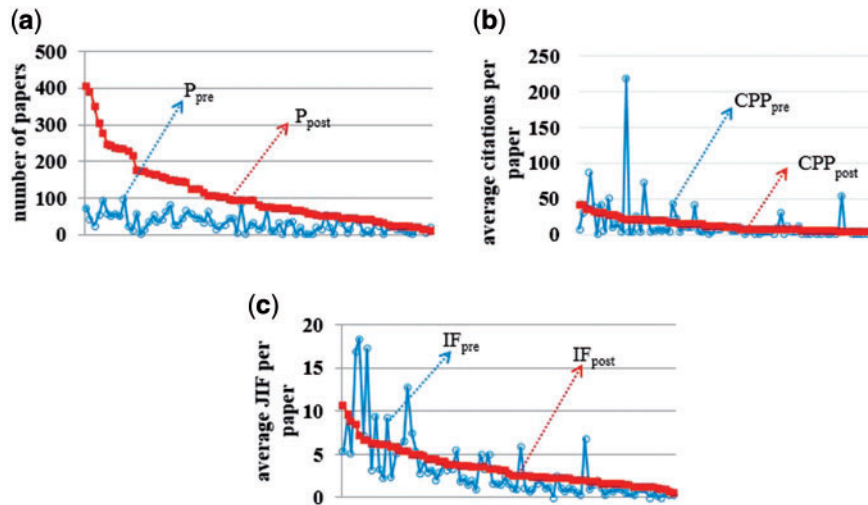$$\text{Equation (11)}$$

where $\#FCLA_{pre}$ and $\#FCLA_{post}$ represent the numbers of papers for which the scholar was the first, corresponding, or last author between 1996 and 2005 and between 2006 and 2015, respectively. $FCLA_i$ represents the number of papers for which the scholar was the first, corresponding, or last author in year i.

12. $\%FA_{pre}$ and $\%FA_{post}$

$$\%FA_{pre} = \frac{\#FA_{pre}}{P_{pre}} \qquad \%FA_{post} = \frac{\#FA_{post}}{P_{post}} \qquad \text{Equation (12)}$$

where $\%FA_{pre}$ and $\%FA_{post}$ represent the proportions of papers for which the scholar was the first author between 1996 and 2005 and between 2006 and 2015, respectively.

Figure 1. (a) Number of papers, (b) average citation count per paper, and (c) average JIF per paper of each scholar before and after receiving the award, with scholars spaced along the *x*-axis.

13. $\%CA_{pre}$ and $\%CA_{post}$

$$\%CA_{pre} = \frac{\#CA_{pre}}{P_{pre}} \qquad \%CA_{post} = \frac{\#CA_{post}}{P_{post}} \qquad \text{Equation (13)}$$

where $\%CA_{pre}$ and $\%CA_{post}$ represent the proportions of papers for which the scholar was the corresponding author between 1996 and 2005 and between 2006 and 2015, respectively.

14. $\%LA_{pre}$ and $\%LA_{post}$

$$\%LA_{pre} = \frac{\#LA_{pre}}{P_{pre}} \qquad \%LA_{post} = \frac{\#LA_{post}}{P_{post}} \qquad \text{Equation (14)}$$

where $\%LA_{pre}$ and $\%LA_{post}$ represent the proportions of papers for which the scholar was the last author between 1996 and 2005 and between 2006 and 2015, respectively.

15. $\%FCLA_{pre}$ and $\%FCLA_{post}$

$$\%FCLA_{pre} = \frac{\#FCLA_{pre}}{P_{pre}} \qquad \%FCLA_{post} = \frac{\#FCLA_{post}}{P_{post}}$$
$$\text{Equation (15)}$$

where $\%FCLA_{pre}$ and $\%FCLA_{post}$ represent the proportions of papers for which the scholar was the first, corresponding, or last author between 1996 and 2005 and between 2006 and 2015, respectively.

Each of these pairs of indicators was calculated for each individual to provide a ground for comparing the 83 Cheung Kong Scholars' research output and coauthorship patterns before and after receipt of the award. We conducted a series of comparative analyses based on the following aspects:

1. To analyze changes in the scholars' research output in terms of their number of papers, average citations per paper, and average JIF per paper, we created three comparison charts, there are two lines in each chart, one line represents the preaward (1996–2005) period, and another one represents the postaward (2006–15) periods, and conducted a Wilcoxon signed-rank test.
2. To analyze the overall and dynamic trends of the research output of each individual, we drew a quadrant diagram based on paper quantity and citations.

3. We analyzed the changes in coauthorship patterns, including the number of coauthors per paper and what position the scholar had in the list of authors for each paper. Specifically, we analyzed whether there were significant differences in the number and proportion of first-author, corresponding-author, or last-author papers by each scholar in the two time periods, and we also calculated the numbers and proportions of papers for which the scholar was the first, corresponding, or last author in the two time periods.

3 Results

3.1 Research output in the preaward and postaward periods

Research output is considered a key part of a university or academic's achievements and is typically defined by the quantity and quality of the research published by a researcher, department, or institution within a specific time frame. Bibliometric measures can be used to assess research output. Because number of research papers is the most standard representation of knowledge output (Koys 2008; Shepherd, Carley and Stuart 2009), we have chosen to provide an in-depth analysis of this criterion. Equally important is the impact of the research reported in those papers, which is not only related to the quality of the research but also a goal in itself. Research impact is often measured using citation-based parameters (Bekkers 2017), which means citations can be used to measure scholars' impact. We have also taken JIF into consideration for evaluating the channels of publication of each scholar's research output. These indicators were used to evaluate the research output in terms of both quantity and quality.

For each scholar and each time period (1996–2005 and 2006–15), we calculated the number of papers (P_{pre} and P_{post}), average citation counts per paper only for citations within the investigated time period (CPP_{pre} and CPP_{post}), and average JIF per paper (IF_{pre} and IF_{post}).

Figure 1 plots the number of papers, average citation counts per paper, and average JIF per paper for each scholar during the two time periods. Each node represents the performance of one scholar
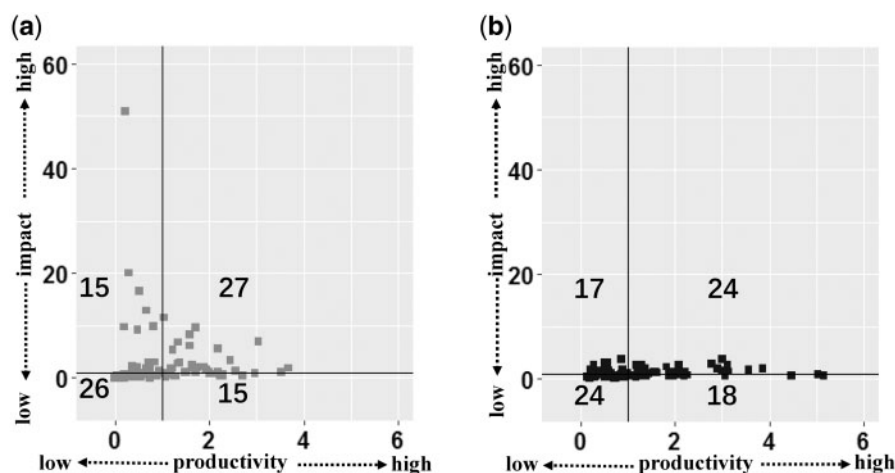
Figure 2. Distribution of individuals based on their productivity and impact in the (a) preaward and (b) postaward periods.

during a certain period, with circle nodes representing the scholars' preaward performance and rectangle nodes representing their postaward performance. Thus, Figure 1 shows the differences between the two time periods in terms of the three aforementioned aspects. Figure 1a indicates that most Cheung Kong Scholars had considerable ability to publish research papers and published more papers after receiving the award. This is consistent with Bekkers (2017), which also discovered a positive development in the output of awardees. Of course, not all scholars published numerous papers. We do not analyze the underlying reasons for this, but Cao and Suttmeier (2001) reported that some researchers claimed to be too busy or pressed by other business to publish abroad. In certain disciplines, reluctance to publish can also arise from concerns about the protection of intellectual property rights. We conducted a Wilcoxon signed-rank test to compare the scholars' performance, as measured by the three research output indicators, during the preaward and postaward periods. The results presented in Table 2 revealed that almost all the Cheung Kong Scholars published significantly more papers in the 10 years after receiving the award compared with the prior 10 years, with a median of 27 and 78 papers per scholar during the preaward and postaward periods, respectively. Significant differences were determined in the average number of citations per paper and average JIF per paper, with a median of 4.32 and 10.73 citations per paper and JIF of 1.69 and 2.79 per paper during the preaward and postaward periods, respectively. Different disciplines may have resulted in different performance levels, but the scholars in all four disciplines had superior performance in the 2006–15 period. The number of papers and citations per paper for the medicine and natural sciences scholars was consistently higher in the two time periods, but engineering scholars had the most papers per scholar in the second period. When scholars were divided into two groups based on the age at which they won the Cheung Kong Scholars Award (31–40 and 41–49 years), we discovered that scholars in the 41–49 years group exhibited more favorable performance in the postaward period than in the preaward period in terms of the three aforementioned aspects; scholars in the 31–40 years group had a significant increase in terms of the number of papers published but not in terms of the average citations per paper and the average JIF per paper (Table 2). Overall, our results suggested that not only was there a significant increase in the number of papers published but quality was also improved.

3.2 Relative positional change based on productivity and impact

In the previous section, we analyzed the changes in the research output of the 83 Cheung Kong Scholars as a whole. Next, we evaluated their individual performance and classified them into four types according to their productivity and research impact. The performance of each scholar was compared with the median performance of all the Cheung Kong Scholars, so that each person's strengths and weaknesses could be elucidated. We were interested in individual variance in the scholars' performance, and our questions were, 10 years after receipt of the award, which individuals were in more prominent positions and who in less favorable positions. Our goal was to improve the understanding of Cheung Kong Scholars' characteristics, and the results can be used in the further selection of talented researchers.

The median performance of the 83 scholars was used as a reference and normalized to 1. Publications and citations during the two time periods were processed separately to achieve different baselines. In the preaward period, the median paper count was 27, and the median of average citations per paper was 4.32; in the postaward period, the median paper count was 78, and the median of average citations per paper was 10.73. Each scholar's performance in the preaward and postaward periods was compared with these two baselines. The normalized indicators NP_{pre}, NP_{post}, $NCPP_{pre}$, and $NCPP_{post}$ represent each scholar's relative performance in publication count and citations per paper. If the value is equal to 1, the scholar's performance was equal to the median of all the scholars during that time period.

We categorized the 83 scholars according to their productivity and impact performance into four groups corresponding to four quadrants in Figure 2. The horizontal axes represent productivity (NP_{pre} and NP_{post}), and the vertical axes represent impact ($NCPP_{pre}$, and $NCPP_{post}$). The intersection coordinate is (1, 1), which represents the median performance of all the scholars. The productivity and impact of the scholars in the upper-right quadrant (Quadrant I, impact > 1 and productivity > 1) were both higher than the median. The scholars in the upper-left quadrant (Quadrant II, impact > 1 and productivity < 1) had above-median scientific impact but below-median productivity. The scholars in the lower-right quadrant (Quadrant IV, impact < 1 and productivity > 1) were more productive, but their impact was lower than the median. The
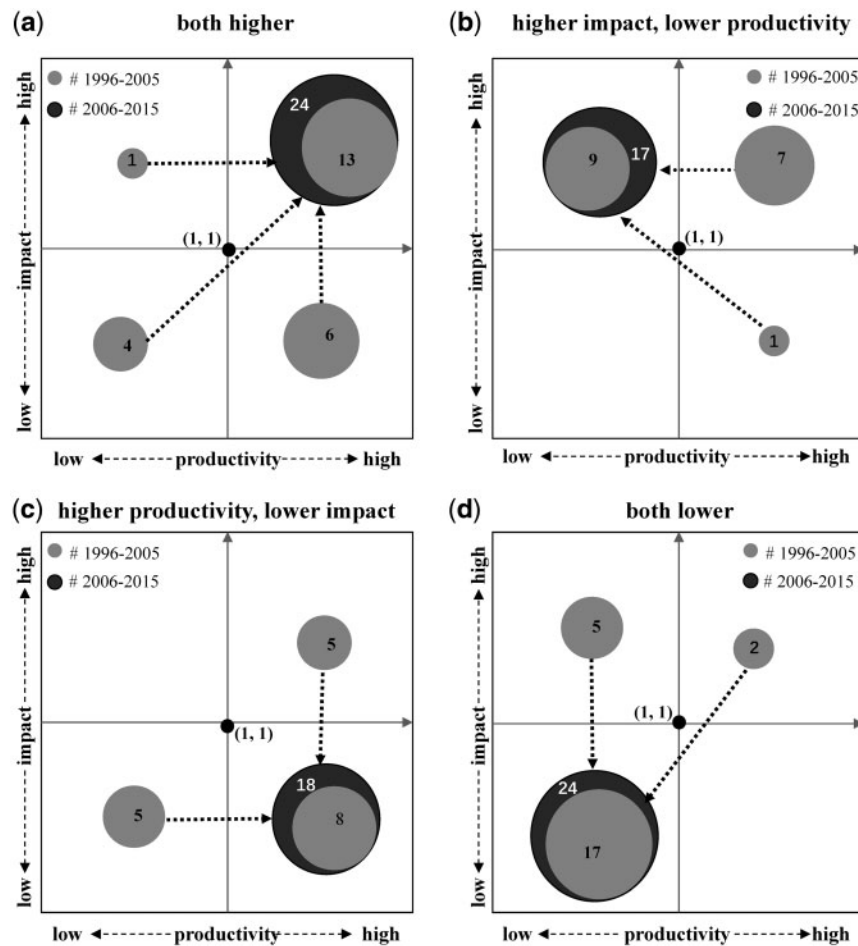
Figure 3. Categories of positional change based on two dimensions: productivity and impact.

impact and productivity of scholars in the lower-left quadrant (Quadrant III, impact < 1 and productivity < 1) were both lower than the median level.

Figure 2a displays the scholars' performance in the preaward period, whereas Figure 2b plots that in the postaward period. It can be observed that there are considerably more scholars in the first and third quadrants in both the preaward and postaward periods. The distribution of impact in the postaward period is considerably more concentrated than in the preaward period, and several scholars become more prominent in productivity than others in the postaward period.

In the preaward period, each scholar has an initial position in the quadrant diagram, and in the postaward period, each of them also has a final position. We further defined four categories according to these scholars' transition of positions, as follows:

1. 'both higher' (The final position is in Quadrant I.)
2. 'higher impact, lower productivity' (The final position is in Quadrant II.)
3. 'higher productivity, lower impact' (The final position is in Quadrant IV.)
4. 'both lower' (The final position is in Quadrant III.)

Scholars in category of 'both higher' are considered the best. Their productivity and impact are both higher than the median level, whereas category of 'both lower' indicates a relatively unfavorable trend.

Figure 3 illustrates the transitions of scholars in each of the four categories. In each figure, the sizes of the circles reflect the proportion of scholars belonging to that group. The light colour circles denote the scholars' initial positions in 1996–2005, and the dark colour circles denote the scholars' final positions in 2006–15. The arrows represent the direction of the scholars' movement from one period to the next.

(1) Both higher
Figure 3a demonstrates that scholars in this category had above-median scientific impact and productivity after receipt of the award. The four light colour circles denote the four initial positions of the 24 scholars. The largest circle reveals that 13 scholars remained in Quadrant I; therefore, they achieved optimal research performance. Among the 11 other scholars, 4 changed from having the least favorable productivity and impact to the most favorable. To understand the reasons for this improvement, we examined the four scholars' résumés. Two of these scholars were engineering scientists, one was a medical scientist, and one was an agricultural scientist. All of them obtained their PhDs in China and had won numerous prizes after receiving the Cheung Kong Scholars Award, such as first place in the Natural Science Prize of the Ministry of Education, the honor of Chief Scientist, and the National Scientific and Technological

Table 2. Results of the Wilcoxon signed-rank test in terms of publication count, average citations per paper, and average JIF per paper for the preaward and postaward periods

Variable	Award-winning age	Preaward (1996–2005) Median (range)	Postaward (2006–15) Median (range)	P
Publication counts per scholar	All of scholars	27 (0, 99)	78 (10, 402)	0.000*
	31–40	21.5 (1, 59)	91.5 (15, 392)	0.000*
	41–49	29 (0, 99)	77 (10, 402)	0.000*
Average citation counts per paper	All of scholars	4.32 (0, 219.17)	10.73 (2.29, 40.93)	0.000*
	31–40	6.35 (0.27, 86.38)	13.32 (2.47, 40.93)	0.130
	41–49	3.96 (0, 219.17)	8.35 (2.29, 40.56)	0.001*
Average JIF per paper	All of scholars	1.69 (0, 18.39)	2.79 (0.58, 10.71)	0.000*
	31–40	2.90 (0.30, 19.39)	3.46 (0.58, 8.55)	0.209
	41–49	1.27 (0, 17.24)	2.47 (0.62, 10.71)	0.000*

*P < 0.05 denotes statistical significance.

Progress Award, one of the five most important national prizes awarded by the State Council for science and technology. The receipt of so many awards indicated that these four scholars accomplished remarkable achievements through their scientific research. A more in-depth analysis on the reasons for this marked improvement requires a case study approach, which is worth considering for further studies. One of the other seven scholars improved their productivity and had continued to have a high impact. The other six scholars improved their impact and maintained high productivity.

(2) Higher impact, lower productivity

Figure 3b corresponds to scholars whose scientific impact improved but who did not achieve a similar improvement in productivity. These 17 scholars were distributed throughout the three quadrants before receiving the award; the position of nine scholars remained unchanged. The transitions suggest that the academic community became more aware of the work by these scholars, but their productivity was lower than that of other Cheung Kong Scholars. This may have been due to various reasons, such as holding academic and management jobs simultaneously. Seven scholars dropped from Quadrant I, suggesting that both their productivity and impact had initially been higher than the median. After 10 years, they still had a high impact but were unable to maintain their productivity. Another scholar improved their impact but experienced a decrease in productivity to the below median level in the 2006–15 period.

(3) Higher productivity, lower impact

Figure 3c presents scholars whose productivity substantially improved but whose impact did not; there were 18 scholars in this group, and 8 of them remained unchanged. In total, 5 of the other 10 scholars improved their productivity but still had a below-median impact. Another five scholars dropped from the most favorable quadrant; they maintained their productivity but experienced a decrease in impact to the lower median level in the postaward period. We examined these five scholars' résumés and found that two of them underwent a considerable decrease in impact in terms of absolute values, although they had a slight increase in papers published. The other three scholars experienced substantial increases in impact and productivity in terms of absolute values; however, due to the high median value for impact in the 2006–15 period, this increase was not sufficient for these scholars to reach the median level.
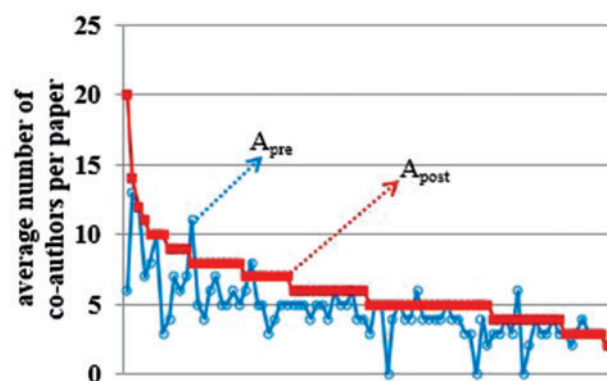

Figure 4. Average number of coauthors per paper.

(4) Both lower

Figure 3d corresponds to scholars who had productivity and impact both lower than the median values in the postaward period. A total of 24 scholars were in this position, and two scholars had dropped from the most favorable category. To understand the reason for this decrease, we examined the two scholars' résumés. One was 37 years old, and the other was 46 years old at the time of the award, and they had a slight increase in the absolute numbers of papers they published and their scholarly impact; however, their slight increases in productivity and impact were not sufficient to match the median level of the other scholars. Furthermore, they did not receive any other major scientific and technological awards after receiving the Cheung Kong Scholars Award. The positions of 17 scholars were unchanged. The award-winning age of these scholars was mainly 42–45 years (one was 37 years, two were 39 years, one was 46 years, and one was 49 years), which is regarded as a mature period in the career of a scientist, and almost of these scholars had engineering science backgrounds (one was an agricultural scientist, one was medical scientists, and three were natural scientists). However, from their individual data, their median productivity and impact improved during the second period (only one experienced a decrease in the number of papers published and one had a decrease in average citations per paper); their locations in Quadrant III indicate that their improvements were less pronounced than those of other scholars. The other five scholars had moved from Quadrant II into Quadrant III. Not only did they not have an increase the number of papers they published but they also experienced a reduction in

Table 3. Results of the Wilcoxon signed-rank test of coauthorship patterns for the preaward and postaward periods (# = number, % = proportion)

Variable	Award-winning age	Preaward (1996–2005) Median (range)	Postaward (2006–2015) Median (range)	P
# of coauthors per paper	All of scholars	4.28 (0, 12.83)	5.43 (2.18, 20.23)	0.000*
	31–40	4.12 (1.55, 12.25)	5.80 (2.18, 11.68)	0.000*
	41–49	4.47 (0, 12.83)	5.35 (2.18, 20.23)	0.000*
# of first-author papers	All of scholars	8 (0, 27)	3 (0, 68)	0.000*
	31–40	7 (0, 26)	4 (0, 22)	0.035*
	41–49	8 (0, 27)	3 (0, 68)	0.005*
# of corresponding-author papers	All of scholars	8 (0, 44)	23 (2, 194)	0.000*
	31–40	7.5 (0, 37)	21.5 (3, 144)	0.000*
	41–49	9 (0, 44)	24 (2, 194)	0.000*
# of last-author papers	All of scholars	2 (0, 30)	22 (1, 192)	0.000*
	31–40	1 (0, 15)	15 (0, 192)	0.000*
	41–49	3 (0, 30)	22 (1, 171)	0.000*
# of first-author, corresponding-author, or last-author papers	All of scholars	16 (0, 79)	52 (5, 241)	0.000*
	31–40	13 (1, 42)	54 (10, 218)	0.000*
	41–49	17 (0, 79)	52 (5, 241)	0.000*
% of first-author papers	All of scholars	25.00% (0, 100%)	4.17% (0, 41.18%)	0.000*
	31–40	40.00% (0, 100%)	3.97% (0, 31.82%)	0.000*
	41–49	22.58% (0, 100%)	4.17% (0, 41.18%)	0.000*
% of corresponding-author papers	All of scholars	40.00% (0, 100%)	30.77% (3.41%, 79.84%)	0.243
	31–40	47.25% (0, 78.72%)	31.33% (9.78%, 72.73%)	0.475
	41–49	38.71% (0, 100%)	28.57% (3.41%, 79.84%)	0.531
% of last-author papers	All of scholars	10.64% (0, 100%)	25.15% (4.00%, 79.17%)	0.000*
	31–40	7.67% (0, 36.36%)	25.79% (0, 78.69%)	0.000*
	41–49	11.76% (0, 100%)	25.00% (4.00%, 79.17%)	0.000*
% of first-author, corresponding-author, or last-author papers	All of scholars	65.12% (0, 100%)	66.91% (19.64%, 99.18%)	0.577
	31–40	73.03% (28.57%, 100%)	65.77% (32.00%, 90.91%)	0.361
	41–49	63.64% (0, 100%)	67.11% (19.64%, 99.18%)	0.227

*P < 0.05 denotes statistical significance.

impact. Among these five scholars, one scholar's average citations per paper was reduced considerably, from 55.50 to 3.90, and the number of papers this scholar published was low in both time periods (10–20). We also revealed that some of these scholars held administrative posts at universities or research institutes.

According to the scholars' positional changes in the quadrant diagram, we determined their individual characteristics based on research productivity and impact. Ten years after receiving the award, 47 scholars (56.63%) still remained at their original level in terms of impact and productivity, but the other 36 scholars (43.37%) changed their positions. Furthermore, four scholars moved from being in the least favorable position to the optimal position, and two dropped from the optimal position to the least favorable position. We conducted an analysis of the reasons for these marked changes, but a more in-depth analysis requires a case study approach, which is worth considering for future studies.

3.3 Comparative analysis of coauthorship patterns

Cooperation is always the mainstream, and the 83 Cheung Kong Scholars published a total of 11,522 papers between 1996 and 2015, of which only 125 were single-author papers. A total of 11,397 papers were thus coauthored, a coauthorship rate of 98.92%. When multiple researchers are involved in research collaboration, there is often debate about what order the authors should be listed in a paper. In general, the first and corresponding authors are considered the two most influential in the paper creation

process; in some cases, the last author also has certain significance. For this reason, we calculated the average number of coauthors per paper and the number and proportion for which the scholars were first authors, corresponding authors, and last authors in papers for each time period. In addition, we also calculated the number and proportion of papers for which they were credited as the first, corresponding, or last author in the two time periods. A Wilcoxon signed-rank test was used to compare the coauthorship patterns of the scholars in the two time periods.

The results presented in Figure 4 reveal that, compared with the preaward period, the average number of coauthors per paper was higher in the postaward period. We discovered a significant difference in the number of coauthors from Table 3, which increased from a median number of 4.28 during the preaward period to 5.43 during the postaward period. When scholars were divided into two groups based on their award-winning age (31–40 and 41–49 years), we discovered scholars in both age groups exhibited the same trends, which can be observed in Table 3. Our findings were similar to those of Lehman et al. (2017), who analyzed the authorship trends of publications in the *Journal of Arthroplasty* over a 30-year period and concluded that there was a significant increase in the number of authors per publication, from 3.45 in 1986 to 4.98 in 2015.

We have demonstrated herein that the number of papers by each scholar increased significantly over time, but it is unclear whether this higher research output was accompanied by a more significant role in the coauthorship of papers. Theses 83 Cheung Kong Scholars had a total of 1,142 first-author papers between 1996 and 2015
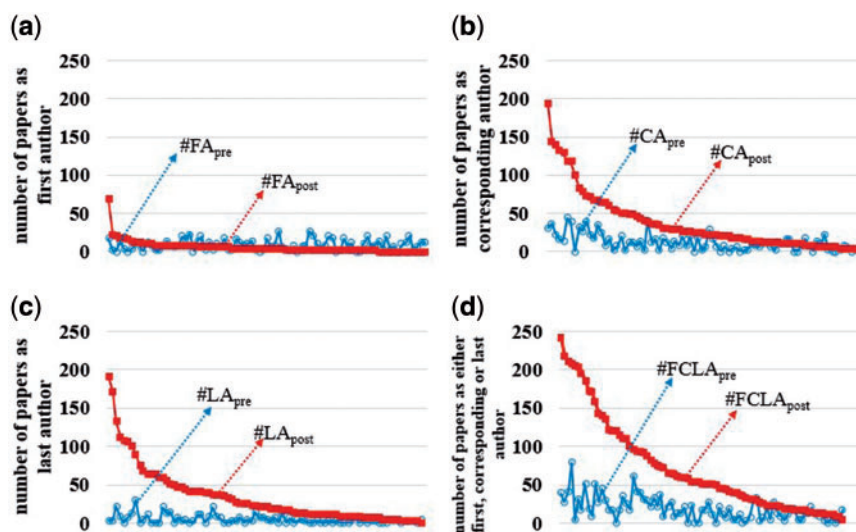
Figure 5. The number of (a) first author, (b) corresponding author, (c) last author, and (d) first-author, corresponding-author, or last-author papers for each scholar before and after receiving the award with scholars spaced along the *x*-axis.

(703 papers in the preaward period and 439 in the postaward period), accounting for 9.91% of their total publications. Collectively, they had a total of 3,997 corresponding-author papers (950 vs. 3,047), contributing to 34.69% of their publications overall, and 3,183 last-author papers (382 vs. 2,801, not including those for which the scholar was listed as both the corresponding and last author), accounting for 27.63% of all papers. Furthermore, they had a total of 7,486 papers for which they were the first, corresponding, or last author (1,533 vs. 5,953), accounting for 64.97% of their total publications. Figures 5a–d and 6a–d present comparisons of the time periods for the three types of coauthorship roles, regarding number of papers and proportion of papers, respectively.

Figure 5a reveals that most scholars had fewer first-author papers in the postaward period than the preaward period. Figure 5b and c indicate that almost all of the scholars had a more corresponding-author and last-author papers in the 10 years after receiving the award. Furthermore, Figure 5d indicates that almost all of the scholars published more papers for which they were the first, corresponding, or last author in the postaward period. Known from Table 3, significant differences were identified in the number of papers published under the different authorship roles in each period. Specifically, the number of first-author papers was significantly decreased, from a median of eight papers in the preaward period to three in the postaward period; the number of corresponding-author papers increased significantly, from a median of 8 to 23 papers; the number of last-author papers significantly increased, from a median of 2 to 22 papers; and the number of papers for which the scholars were the first, corresponding, or last author also significantly increased, from a median of 16 to 52 papers. Through analyzing scholars in two age groups (31–40, 41–49 years), we discovered the same trends: scholars in both age groups had significant differences in the number of papers for which they act as the first, corresponding, or last author between two time periods, as shown in Table 3.

Figure 6 illustrates the changes in coauthorship roles from the perspective of the proportion of first-author, corresponding-author, and last-author papers for each scholar before and after receipt of the award. Figure 6a reveals that most scholars had a lower proportion of first-author roles in papers in the postaward period than the preaward period, whereas Figure 6c indicates that almost all of the scholars had a higher proportion of last-author roles in the 10 years after receiving the award. Significant differences were determined in the proportion of first-author and last-author papers in each period from Table 3. Specifically, the proportion of first-author papers was significantly decreased, from a median of 25.00% in the preaward period to 4.17% in the postaward period; the proportion of last-author papers was significantly increased, from a median of 10.46% to 25.15%. However, no significant difference was noted regarding the proportion of corresponding-author papers between the two time periods (median of 40.00% vs. 30.77%), and no significant difference was noted in terms of the proportion of papers for which scholars were the first, corresponding, or last author (median of 65.12% vs. 66.91%). For scholars in different age groups (31–40, 41–49 years), we obtained the same result: scholars in any age group were more likely to be a last author rather than a first author in the postaward period, and no significant change was observed in the incidence of corresponding author roles or in terms of the proportion of papers for which the scholars were the first, corresponding, or last author. Regarding different disciplines, because of the small number of scholars with each discipline, we did not perform a significance test but found that there were similar trends in each type of coauthorship role.

4 Discussion and conclusion

The main findings of this article are as follows. First, the number of papers published by our sampled scholars was significantly higher after they received the Cheung Kong Scholars Award in 2005, from a median of approximately 27 SCI/SSCI papers per person in 1996–2005 to 78 papers per person in 2006–15. The scholars' average citation counts per paper and average JIF per paper were also significantly higher in the second time period, which means these Cheung Kong Scholars improved their output in terms of both quantity and quality, which is similar to the findings of several studies. For example, Gerritsen et al. (2013) discovered that scholars who received
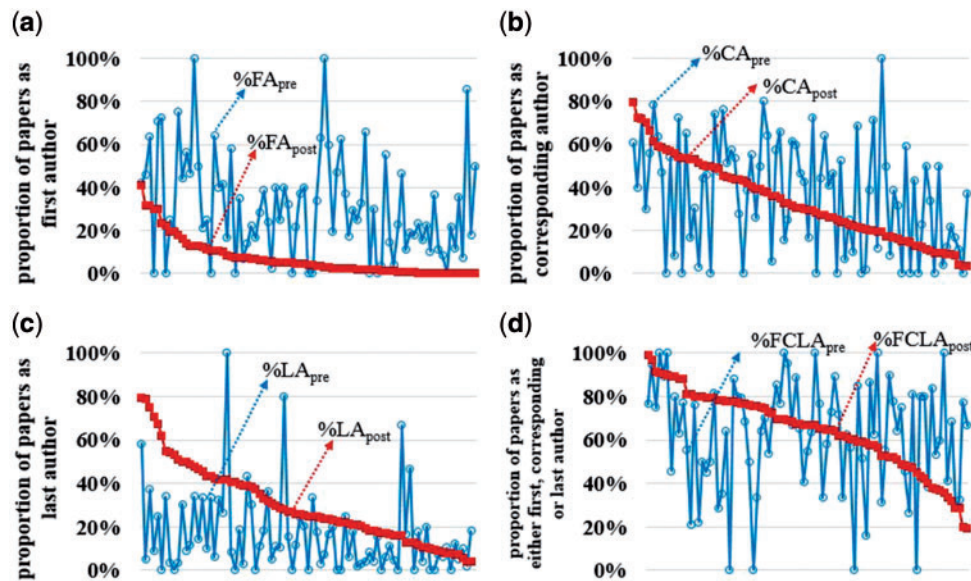
Figure 6. Proportion of (a) first author, (b) corresponding author, (c) last author, and (d) first-author, corresponding-author, or last-author papers for each scholar before and after receiving the award, with scholars spaced along the *x*-axis.

research grants tended to be more successful; Bloch, Graversen and Pedersen (2014) found that research funding had a positive influence on the performance of researchers; and Jacob and Lefgren (2011) demonstrated that scholars' scientific research production increased by 20% in the 5 years after receiving funding from the National Institutes of Health (NIH). Second, as demonstrated through quadrant diagrams, we revealed that the impact of Cheung Kong Scholars was more concentrated in the postaward period than in the preaward period, and several scholars had more prominent productivity in the postaward period. Third, the scholars' coauthorship patterns changed significantly after receiving the award—not only in terms of their number of coauthors per paper but also their authorship role. The number of coauthors per paper of each Cheung Kong scholar was significantly higher after receiving the award. Our analysis suggests that the authorship role of the scholars changed; they were less likely to be listed as the first author of a paper after receiving the award, not only in terms of number but also in terms of proportion. Furthermore, the number and proportion of papers in which they were listed as the last author increased markedly. Additionally, they published more corresponding-author papers and more papers for which they were the first, corresponding, or last author, though the proportion of papers they published did not change significantly. These results suggest that the Cheung Kong Scholars' roles in research collaborations changed after they received the award; to some extent, this shift also reflects improved team building and an expansion of the scholars' scientific research cooperation networks.

In this study, we used whole counting to calculate the scholars' productivity and citation counts. In addition, we conducted a separate analysis using fractional counting and compared the results between these two methods. A comparison of these results revealed no significant differences between the results of the whole-counting and fractional-counting methods. Thus, the major findings of this study were valid regardless of the counting method used.

Because of rapid advancement in technology and deepening economic globalization, the recruitment and retention of talent is essential for sustainable development in the economy and society (Wang 2014). Although the selection of talent requires strict rules, evaluating whether talent programs have achieved their original goals is crucial. Most talent programs are designed as both a reward and an incentive—that is, a reward for past contributions to science and an incentive for future contributions. At present, most Chinese talent programs are focused on the development and implementation of talent recruitment rather than the supervision and evaluation of awardees. Evaluations are occasionally conducted, but systematic supervision and evaluation mechanisms have not yet been established. As a result, the effectiveness of these programs is questionable. The fact that numerous programs do not even release their list of awardees makes it even more difficult to measure the programs' success (Yang 2015).

The original reason for establishing the Cheung Kong Scholars Program was to strengthen China's scientific research power. The Ministry of Education has issued measures for evaluating the Cheung Kong Scholars Program, requiring all colleges and universities to assess and supervise the work of their Cheung Kong faculty scholars and submit these reports to the Ministry of Education for inspection and evaluation. However, there is a lack of established rules or standards for how to complete this assessment, as the directions do not mention any specific assessment methods. In this study, we used quantitative bibliometric indicators to evaluate the research performance of Cheung Kong Scholars. Our results confirm that the Cheung Kong Scholars Award had a positive impact on researchers' output. From the perspective of paper quantity and quality, the award appears to have led to improvements in both factors; there was a considerable increase in quantity, and improvements in quality were also noted. Quantity is only one aspect of evaluation; quality should also be considered when evaluating research performance. In this study, citation count and JIF were employed as indicators of quality, and our results revealed a significant increase in these two indicators. Since the implementation of the Cheung Kong Scholars Program, China has recruited numerous young and excellent academic researchers from both home and abroad,

creating a mutually favorable situation for both scientific research and personnel training. Over its 20 years of operation, there is no doubt that this program has greatly enhanced China's worldwide academic status and the competitive strength of its universities. Further analysis confirmed that the coauthorship pattern of the researchers changed after receiving the Cheung Kong Scholars award. These findings are in line with our expectations, as researchers usually assume different responsibilities at different points in their career. Whether this change in authorship pattern is beneficial for the development of scientific research is worthy of further discussion, and interview methods should be used in future studies. China's Ministry of Education should take these quantitative indicators into consideration alongside peer review evaluations; attention should be paid to the differences between various disciplines; and stronger supervisory mechanisms should be established to effectively promote the development of a high-level talent team.

We should mention some limitations of the present study. First, this study only focused on the 83 scholars who received the award in 2005, and this resulted in discipline-related bias. In future studies, we plan to expand our research to include Cheung Kong Scholars from different years and may limit the sample to a single discipline. Second, we did not take more deep considerations about the publishing life cycle of scholars, but we will attempt to do so in future research. Third, the list of all applicants for the award was not disclosed by the award committee, which limited our research goals; we were only able to study the differences between the preaward and postaward performance of the awardees, not the difference in academic performance between those winning and not winning the award. Therefore, in future research, we will attempt to communicate with the administration to obtain a list of non-award-winning applicants and analyze the effect of the award on the researchers in more detail rather than simply tracking their research performance before and after the award. Fourth, this study only investigated research output in the form of SCI/SSCI papers, but there are other kinds of research output that could be considered, such as monographs and patents. Each discipline places a unique value on each form of research output. For example, engineering researchers focus on obtaining patents or designing products; academic papers represent very little of their research output. Therefore, future studies should consider measuring different kinds of research output based on their value in each discipline. Beyond that, however, we did not consider Chinese-language papers because we were mainly concerned with the contribution of scholars to internationally influential research. However, in our research process, we discovered that several scholars had published more Chinese-language papers than SCI/SSCI papers; therefore, in analyzing research performance, their Chinese-language papers should be taken into consideration to ensure research rigor. Through this method, we will improve our research by considering as many languages as possible. Fifth, although we used bibliometric methods to quantitatively analyze the change in research output of the Cheung Kong Scholars, it is difficult to evaluate the creativity and novelty of research activities, and we have not accounted for changes in the scholars' careers, such as changing employment, promotion, or shift of career focus. Bibliometric indices can play a supporting role and supplement the peer review process with important information; in our future research, we plan to combine qualitative semistructured interviews, peer reviews, and other methods to perform a more in-depth analysis. Using both bibliometrics and peer review will inevitably result in mixed outcomes. For example, one scholar's number of papers or

citations has increased considerably according to bibliometric analysis, but in peer review, the same scholar may be considered poor performing. This is because peer review is not only concerned with an increase in quantity, but also on whether the quality of papers has improved. For coauthored papers, peer reviewers tend to pay more attention to the role of the author in the research team: whether the researcher assumed a leadership role or was listed as an author despite not made a considerable effort to the paper's creation. Once the Cheung Kong Scholars Award or higher honors have been conferred on an individual, there is a possibility that they will be offered honorary authorship in papers. A scholar's research output may perform well in peer review despite having a poor bibliometric score; each discipline focuses on specific forms of research output, and each type of output requires a different amount of effort to produce. For more effective evaluation, peer review and bibliometric methods should be used together.

Finally, in this study, we were unable to conduct specific, individual analyses for each scholar because of privacy concerns. Some scholars significantly increased their research output, whereas that of others decreased, but we could not analyze the individual reasons for this. In our future studies, we will attempt to address this problem by combining bibliometric data with interviews.

References

Bekkers, D. (2017) '*China's Pursuit of Overseas Brains: The 1, 000 Talents Policy*', <https://www.rvo.nl/sites/default/files/2017/01/1000-Talents-Policy-Article.pdf>.

Bloch, C., Graversen, E. K., and Pedersen, H. S. (2014) 'Competitive Research Grants and Their Impact on Career Performance', *Minerva*, 52/1: 77–96.

Camp, M., and Escott, B. G. (2013) 'Authorship Proliferation in the Orthopaedic Literature', *The Journal of Bone and Joint Surgery. American Volume*, 95/7: e44.

Cao, C., and Suttmeier, R. P. (2001) 'China's New Scientific Elite: Distinguished Young Scientists, the Research Environment and Hopes for Chinese Science', *China Quarterly*, 168: 960–84.

Chan, H. F., Gleeson, L., and Torgler, B. (2014) 'Awards before and after the Nobel Prize: A Matthew Effect and/or a Ticket to One's Own Funeral?', *Research Evaluation*, 23/3: 210–20.

Chan, H. F., Onder, A. S., and Torgler, B. (2015) 'Do Nobel Laureates Change Their Patterns of Collaboration following Prize Reception?', *Scientometrics*, 105/3: 2215–35.

Cunningham, S. J., and Dillon, S. M. (1997) 'Authorship Patterns in Information Systems', *Scientometrics*, 39/1: 19–27.

Cvetanovich, G. L. et al. (2015) 'Publication and Level of Evidence Trends in the American Journal of Sports Medicine from 1996 to 2011', *American Journal of Sports Medicine*, 43/1: 220–5.

Dotson, B. et al. (2011) 'Authorship and Characteristics of Articles in Pharmacy Journals: Changes over a 20-Year Interval', *Annals of Pharmacotherapy*, 45/3: 357–63.

Gao, Y. (2014) 'Research on the Academic Growth Path of the Professor of the Cheung Kong Scholars Program', Doctoral Dissertation, Tsinghua University, Beijing.

Gerritsen, S. et al. (2013) *Up or out? How Individual Research Grants Affect Academic Careers in The Netherlands*. CPB Netherlands Bureau for Economic Policy Analysis.

Godin, B. (2003) 'The Impact of Research Grants on the Productivity and Quality of Scientific Research', INRS Working Paper, Ottawa.

Jacob, B. A., and Lefgren, L. (2011) 'The Impact of NIH Postdoctoral Training Grants on Scientific Productivity', *Research Policy*, 40/6: 864–74.

Koys, D. J. (2008) 'Judging Academic Qualifications, Professional Qualifications, and Participation of Faculty Using AACSB Guidelines', *Journal of Education for Business*, 83/4: 207–13.

Lehman, J. D. et al. (2017) 'Authorship Trends in 30 Years of the Journal of Arthroplasty', *Journal of Arthroplasty*, 32/5: 1684–7.

Levsky, M. E. et al. (2007) 'A Descriptive Analysis of Authorship within Medical Journals, 1995-2005', *Southern Medical Journal*, 100/4: 371–5.

Modi, P. et al. (2008) 'How Many Cardiac Surgeons Does It Take to Write a Research Article?: Seventy Years of Authorship Proliferation and Internationalization in the Cardiothoracic Surgical Literature', *Journal of Thoracic and Cardiovascular Surgery*, 136/1: 4–6.

Neufeld, J. (2016) 'Determining Effects of Individual Research Grants on Publication Output and Impact: The Case of the Emmy Noether Programme (German Research Foundation)', *Research Evaluation*, 25/1: 50–61.

Niu, H., and Zhou, J. Z. (2012) 'A Characteristic Study of the High-Level S&T Talents in China Based on CV AnalysisTaking the Projects of Hundred Talents Program, the Yangtze River Scholar and Outstanding Youth as Examples', *Journal of University of Science and Technology Beijing*, 99/3: 315–6.

Papatheodorou, S. I., Trikalinos, T. A., and Ioannidis, J. P. (2008) 'Inflated Numbers of Authors over Time Have Not Been Just Due to Increasing Research Complexity', *Journal of Clinical Epidemiology*, 61/6: 546–51.

Pinter, A. (2015) 'Changing Authorship Patterns and Publishing Habits in the European Journal of Pediatric Surgery: A 10-Year Analysis', *European Journal of Pediatric Surgery*, 25/4: 353–8.

Reich, M. S. et al. (2014) 'Level of Evidence Trends in the Journal of Bone and Joint Surgery, 1980-2010', *The Iowa Orthopaedic Journal*, 34: 197–203.

Schrock, J. B., Kraeutler, M. J., and McCarty, E. C. (2016) 'Trends in Authorship Characteristics in the American Journal of Sports Medicine, 1994 to 2014', *American Journal of Sports Medicine*, 44/7: 1857–60.

Shepherd, C. D., Carley, S. S., and Stuart, R. S. (2009) 'An Exploratory Investigation of the Periodic Performance Evaluation Processes for Marketing Faculty: A Comparison of Doctoral-Granting and Non-Doctoral-Granting Universities', *Journal of Marketing Education*, 31/2: 143–53.

Sina News. (2005) 'Kongque Donggui Shuoguo Fencheng: Changjiang Xuezhe Jiangli Jihua', Chengxiao Xianzhu [The Cheung Kong Scholars Programme Achieved Remarkable Results], <http://news.sina.com.cn/e/ 2005-03-29/ 14075496367s.shtml> accessed 8 Nov 2017.

The Ministry of Education of the People's Republic of China. (2005) 'Changjiang Xuezhe He Chuangxin Tuandui Fazhan Jihua', Changjiang Xuezhe Pinren Banfa [The requirement of The Cheung Kong Scholar Programme], <http://www.eol.cn/article/20050616/3141021.shtml> accessed 6 Feb 2018.

Wang, L. (2014) 'Research and Countermeasures of Management of the High-Level Overseas Talents', *Open Journal of Social Sciences*, 2/9: 1–5.

Yang, F. (2015) 'Surveying China's Science and Technology Human Talents Programs', *SITC Research Briefs*, 2015/3: 1–15.

Zhang, Z., and Li, X. (2014) 'Barriers and beyond: Analysis of and Thinking about the Overall Status of the Changjiang Scholars of Physics', *Studies in Philosophy of Science and Technology*, 31/3: 107–12.