Long-Term Influences of Interventions in the Normal Development of Science: China and the Cultural Revolution

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Intellectual and technological talents and skills are the driving force for scientific and industrial development, especially in our times characterized by a knowledge-based economy. Major events in society and related political decisions, however, can have a long-term effect on a country’s scientific well-being. Although the Cultural Revolution took place from 1966 to 1976, its aftermath can still be felt. This is shown by this study of the production and productivity of Chinese scientists as a function of their age. Based on the 1995–2000 data from the Chinese Science Citation database (CSCD), this article investigates the year-by-year age distribution of scientific and technological personnel publishing in China. It is shown that the “Talent Fault” originating during the Cultural Revolution still exists, and that a new gap resulting from recent brain drain might be developing. The purpose of this work is to provide necessary information about the current situation and especially the existing problems of the S&T workforce in China.

Introduction

Intellectual and technological talents and skills are the driving force for scientific and industrial development. A nation’s research capacity and its ability to transfer research achievements to other sectors of society are closely related to its knowledge structure. An important aspect of this knowledge structure is the age distribution of a country’s S&T workers. Consequently, also in China, this age structure has been given close attention by administrative departments. In 1985, the Chinese Academy of Sciences completed statistics on the age structure of those scientists who were responsible for a total of 1,270 research projects. Some years later Hu, Cao, Su, Wu, and Nie (1993) used a questionnaire approach in order to obtain statistics on the age of 2,426 authors of research papers. Despite the difference in methods and objects, these two investigations have led to similar results, indicating a clear gap in the use of the country’s inherent talent. The 1985 statistics show a gap between the age of 36 and 40 years and Hu et al.’s statistics, collected about eight years later, demonstrate that the gap had widened to the age span between 32 and 47. According to Hu et al. (1993), the publication peak was situated between 49 and 58 years, 8 years later than the result obtained in 1985.

The reason for this gap is well known. It is the result of the Cultural Revolution, when people with the inherent talent to do S&T work were not given the opportunity to study and acquire the necessary skills. Recently, Liang, Kretschmer, Guo, and Beaver (2001) and Wu et al. (2003), confirmed the continuing existence of this gap in the use of China’s latent talents. The observed phenomenon can be compared with the slowing down in scientific activity (or at least publication) during World War II (Price, 1963, fig. 4, p.18; Van Raan, 2000). Yet the two phenomena are different because Price’s and Van Raan’s observations refer to publications, while ours refer to scientists and their productivity.

Based on 1995–2000 data from the Chinese Science Citation database (CSCD) and by using a bibliometric method, this work investigates the year-by-year age distribution of scientific and technological personnel publishing in China. The purpose of this work is to provide necessary information about the current situation and especially the existing problems of the S&T workforce. We hope that our
discussion will help science policy makers using existing talent more adequately by restructuring and optimizing the scientific environment. Such an environment should foster a contingency of talent fitting in the highly competitive environment of the new century.

This article is a thoroughly revised and extended version of an article (Jin, Li, & Rousseau, 2003) presented during the 9th International Conference on Scientometrics and Informetrics (Beijing, 2003). Some of the main points of this presentation were incorporated in a recent news article published in Nature (Cyranoski, 2003).

The General Age Distribution of Scientists and Their Productivity

Research on the productivity of scientists, institutes, or countries belongs to the core activities of the information sciences and the sociology of science (see, e.g., Price, 1963; Crane, 1965; Reskin, 1977; Fox, 1983; McCann, 2001). Here, however, we focus on the relation between age and productivity.

According to Zhao’s theory of the Optimal Age for Scientific Creativity (Zhao, 1984), a person’s creativity is at its highest between the ages of 25 and 45, reaching a peak around 37 years old. Consequently, if this theory is correct, universities should aim at having most active scientists in that age group. We will investigate to what extent this is true.

The relation between productivity and age has been studied by many researchers. Kyvik (1990), for instance, studied the relationship between age and scientific productivity in Norway. He found that publishing activity reaches a peak in the 45–49-year-old age group and declined by 30% among researchers over 60 years old. He, moreover, found that large differences existed between different fields of learning: in the social sciences, productivity remains more or less at the same level for all age groups, while in the natural sciences, productivity continually decreases with increasing age. This finding corresponds to Diamond’s (1986) observation that for mathematicians quantity and quality of output declined monotonically with age. Total citations peaks, however, came much later.

Zusne (1976), plotting the age-group at which the most significant publication of a group of 213 psychologists took place, found a curve closely following Zhao’s (1984) and Lehman’s (1953) suggestions, with a top in the age group between 35 and 40 years of age. Note, however, that there is a serious difference between plotting one top performance (usually an act of high creativity) and the yearly number of publications. The latter number depends much more on perseverance and acquired scientific power.

Although Simonton (1997) admitted that creative careers are almost infinitely varied, he was able to develop integrative models that explain most of his empirical findings concerning the relation between creativity, productivity, and age.

It has been observed (Kyvik, 1990) that collaborative research can sustain productivity when researchers become older. Differences between the peak performances in different fields, and this over several centuries, were also studied by Liang et al. (1999). These authors even found that, generally, the peak ages for the sciences and for the arts were similar.

Melker (1999), while studying the situation in Russia, found two age distributions for scientists: one for the Academy and industrial institutes, and one for universities. The first one has a bell shape, peaking around the age of 60, the latter one has two peaks: a big one around the age of 25, and a smaller one around the age of 60. He calls the first one a dromedary curve. If such a dromedary curve moves forward in time, the corresponding situation leads to stagnation and then the death of science. Adhering to his analogy, the second situation will be called a camel curve. According to Mary Fox’s review (Fox, 1983), such camel curves are not uncommon.

After this short, and necessarily incomplete, review of earlier work, we will now present our own contribution starting with the data sources used for this investigation.

Source of the Statistics and Basic Data

The used publication data have been obtained from the CSCD, a database constructed by the Documentation and Information Centre of the Chinese Academy of Sciences, and supported by the National Natural Science Foundation of China and the Chinese Academy of Sciences. The database covers more than 600 important journals published in China, including those covered by SCI-Expanded. For more information on this database and its uses, the reader is referred to the following articles, where more details are provided (Jin & Wang, 1999; Rousseau, Jin, Yang, & Liu, 2001; Jin & Rousseau, 2001; Jin et al., 2002b). Besides standard bibliographical and citation information, the CSCD also processes, since 1995, authors’ information such as professional title, gender, and age. Note that, in China, a person’s age does not belong to the private sphere, and hence is published by many scientific journals. Consequently, we were able to use altogether 185,486 records of authors’ ages for the period 1995–2000.

Not all journals, however, provide age data. In 1999, for example, only 487 of the 633 source journals included authors’ ages. Moreover, in most cases, only the first author’s age is given. Hence, this study is for the larger part based on first author’s ages. Only occasionally the ages of other authors are taken into account. According to recent studies by Liang et al. (2001; Liang, Liu, & Rousseau, 2003), this means that our results are based on an underestimation of older scientists, as they often occur last in the authors’ byline. As Chinese authors almost invariably rank authors in the byline according to contribution, we may say that the ages of the first authors are representative for the most active scientists.
Based on these 185,486 records, we calculated, for each year of the 1995–2000 period, the proportion of the articles authored by people of each age class, leading to a list of essential data on the age distribution of first authors, graphically shown in Figure 1. Statistics on the age distribution of the scientific personnel of the People's Republic of China have been obtained from the Educational Statistics Yearbook of China (see Appendix A for more details).

**Authors' Age and Their Production**

Figure 1 shows the complete age distributions for the six analysed years, with authors’ age on the abscissa and percentages on the ordinate. Because of the wide age span (from 18 to 90 years), we will henceforth leave ages under 22 and above 70 out of consideration. The general shape of these curves coincides with a “camel” curve in the beginning years of this period, but slowly evolves into a unimodal one, with a peak for authors in their late thirties. In order to better display the overall development, the curves for the years 1995 and 2000 are shown together in Figure 2. In Jin et al. (2002a), we showed that we may restrict ourselves to first authors’ curves (by comparing them to all authors’ curves).

Comparing the curves for the years 1995 and 2000, we notice that the largest peak corresponds to younger authors.
These scientists received their training in recent years and are probably publishing the results of their graduate work, such as master’s theses and Ph.D. dissertations, and of subsequent research. This peak moves to the right, and hence refers roughly to the same group of persons. In addition to the one situated at age 32, there is another peak around age 57 in 1995. This peak diminishes over the years, and has now almost completely disappeared. It corresponds to older scientists who received their training before the Cultural Revolution (which began in 1966). There is a clear gap corresponding to those scientists who should have received scientific training during the period 1966–1976, but, as is well known, did not receive any education at the time. Only a minority of these later became active scientists. This period corresponds to a period where China wasted the S&T talent it had. Between the two major peaks and the gap due to the Cultural Revolution, we notice several minor peaks and gaps indicating a, probably natural, alteration of small ups and downs.

If we look carefully, we may notice a disturbing trend among the young scientists in Figure 1. On the 1995 curve, we see that the increase in production slows down somewhat around the age of 29. On the year 2000 curve, this is not just a small disturbance anymore, but we notice a widening gap from 28 to 36. It even seems that a new valley is forming (see Fig. 3 for details). Why is this happening? Nowadays many young scientists and technicians showing great promise prefer to go abroad to study (and often stay there), or start working for hi-tech companies (abroad or in China). In all these cases, there is a loss for science, and a possible brain drain for the country.

Three Different Age Groups

Figure 4 shows the relative production of papers depending on the year of birth. In Figure 4, we may distinguish three groups of authors. First, there is the group of scientists born after 1967. These authors have an increasing share in China’s scientific production. Yet, careful examination shows that the year 1972 is a turning point. Authors born in or after 1972 show a fast increase, while those before 1972 a much slower relative increase.

Second, there is the stable group of authors born between 1948 and 1967. Among these authors, we notice a highly productive group and a small group of scientists who keep on working despite the hardship they encountered during the Cultural Revolution.

Third, we see that the authors born between 1930 and 1948 decrease their share in the total scientific production. These scientists are retired or will retire in about 10 year’s time, so that their productivity decreases in a natural way. It is, however, their dedication to scientific research that contributed to the existence and dynamic change of a peak in this age rank. Note also that, based on Figure 4, one could subdivide this group into those born before 1943, and those born between 1943 and 1948. This last group consists of those scientists that had already started their basic university education when the Cultural Revolution began.

So, generally, one could say that the contribution of authors born between 1948 and 1967 stays remarkably constant between 1995 and 2000. Authors born before that period are replaced by authors born after 1967.

Age of Scientific Personnel

Figure 5 shows the distribution of China’s scientific personnel on the level of professor, assistant professor, or
lecturer (complete data are shown in Appendix A). In order not to clutter the picture, we only show the distribution for 3 years. In 1995 and even in 1998, we have a clear bimodal curve. This “camel” curve contrasts with the, perhaps, expected “dromedary” (unimodal) curve. Twenty years after the events of the revolution, its influence on the number of scientific personnel is still clearly visible. For the percentages of publications, based on the age of its authors (see Fig. 2), we noticed a similar phenomenon.

By way of comparison, we also show the corresponding curves for the United States (Fig. 6) and for Flanders (Fig. 7). These curves are clearly unimodal, with a peak in the 45–54 range. Comparing older with more recent data, we notice for the United States a tendency towards the younger side (faculty members becoming relatively younger), while for Flanders we notice a tendency towards the older side.

Relative Productivity

We calculated relative productivity by dividing the percentage of publications in an age group by the percentage of scientific personnel in this group. Clearly, younger scientists and older ones have by far the largest productivity in China. The influence of the Cultural Revolution is even now clearly visible (numbers in bold in Table 1), as scientists that should have had their scientific education during the Cultural Revolution and were trained later (those of ages between 46 and 55 in the year 2000) have the lowest productivity.

Discussion and Conclusions

Before discussing the results and distinguishing features of our data, we would like to make a technical point. It is sometimes stated, or implied (Bayer & Dutton, 1977) that authors should not be compared based on their age, but on the time since they have entered the field, usually taken as the date of their Ph.D. This is then referred to as career age. However, we do not have these data for Chinese authors (and consider ourselves very lucky to be able to have access to authors’ age). Moreover, a number of Chinese faculty members do not have a Ph.D., especially those who suffered the consequences of the Cultural Revolution. We think that our results are interesting enough as they are, without the correction for career age. Using career age would certainly make the gap due to the Cultural Revolution more visible. This, however, would not tell us anything about how a country uses the available scientific brains for the progress of science, according to the population’s age.

One could say that, at least in general terms, the age distribution curve approaches Zhao’s ideal curve. Indeed, in 1979 the Chinese scientometrician Hongzhou Zhao proposed that the optimal period of scientific creativity is between 25 and 45 years, with a top around 37. In the era in which we live, characterized by the dominance of Big Science (big projects, large groups of collaborators) (Price, 1963), it seems likely that, maybe not creativity, but certainly productivity, reaches a peak later on in life.

The age structure of a country’s S&T personnel is the result of a dynamic mechanism. It is governed and shaped by internal as well as external forces. Internal forces include the availability of scientific talent, while social factors and political, economic, and cultural influences act as external forces. Such a study could be placed within the framework of a dynamic and/or social-contextual study of science. For such studies (in general), we refer the reader to Barnes and Edge (1982), Gibbons et al. (1994), and Leydesdorff (1995). The availability of scientific talent is an important input factor. When the S&T personnel age structure becomes...
abnormal due to external events, it takes decades to return to normality, requiring several generations’ efforts. Government policies can play a key role in reshaping such an abnormal situation by encouraging the young to enter the S&T system. Market economy requires new recruiting and motivating mechanisms in order to maintain an adequate contingency of scientific and technological workers. This is vital for the scientific well-being of any country. Major external events such as the Cultural Revolution or a prolonged period of war or social revolt, however, may have irreversible consequences as shown by our data. Just after the People’s Republic of China was founded in 1949, a number of scientists returned from abroad and became the pioneers of science in China. Similarly, a generation of intellectuals trained in China before the Cultural Revolution, became a major force when China started to open in 1979. During the Cultural Revolution, schools were closed, and the youth did not receive a scientific education, leading to an irreversible gap in the use of the available talent. After 1979, China spent a lot of money and effort training young scientific and technological talent. The high peak of scientists in the age group between 30 and 40 shows that the younger generation has taken up the challenge, and that they are the main force in the development of S&T in China.

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References


Note. Figures in bold draw attention to the low productivity of scientists who should have had a university education during the Cultural Revolution (but did not).

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<th>Period</th>
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<th>31–35</th>
<th>36–40</th>
<th>41–45</th>
<th>46–50</th>
<th>51–55</th>
<th>56–60</th>
<th>&gt; 60</th>
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<tr>
<td>1995–1996</td>
<td>2.60</td>
<td>0.94</td>
<td>0.75</td>
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<td>0.72</td>
<td>0.71</td>
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<td>3.16</td>
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<td>0.77</td>
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<td>0.67</td>
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<td><strong>0.46</strong></td>
<td><strong>0.56</strong></td>
<td>0.60</td>
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TABLE 1. Productivity data per age category.
Appendix A. Age and Rank of Full-Time Faculty Members in Colleges and Universities Between 1995 and 2000

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<td>Assistants 1995</td>
<td>60,823</td>
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<tr>
<td>Instructors 1995</td>
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<td>Assistants 1996</td>
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<td>Instructors 1996</td>
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<td>Assistants 1997</td>
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<td>Instructors 1997</td>
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<td>Instructors 2000</td>
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