

The development of female science and technology workers in China: Achievements, problems and suggestions

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Abstract

Female science and technology (S&T) workers have played an increasingly important role in scientific research in China and have made remarkable contributions to that field. Using scientific surveys and publicly available awards data, this paper examines the specific status of female S&T workers, including the workforce structure, their domestic contributions and their international influence. Our analysis reveals the problems encountered by female S&T workers in research output, working time, development opportunities and professional voice, as well as the challenges they face during pregnancy and postnatal nursing. To solve these problems, relevant government departments should introduce more effective steps, respect women's contributions, step up publicity and provide effective assurance policies to promote the long-term and in-depth development of female scientific researchers.

Keywords

Female science and technology workers, women scientists, state of development, contributions to science and technology, international influence

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1. Introduction

The world needs science, and science needs women. The progress of science and technology (S&T) concerns the well-being of all of humanity, which will be incomplete without the participation of women. Women's contribution to science has been well documented throughout history (Zhang, 2019). In recent years, female S&T workers in China have made important contributions to natural science and engineering technology. Women scientists, through their outstanding contributions to or innovative achievements in their fields of expertise, have set a fine example for women's participation in science, technology and innovation (STI), and have projected a positive image in society and the media, inspiring more young women to enter the field of STI. In this study, which aims to establish the growth trajectory of female S&T workers in recent years and present the practical difficulties faced by them, we hope to exert a positive influence on improving the working environment for female S&T workers to enable them to build successful careers for themselves.

2. Development status of female S&T workers in China

Given the growing international attention to the role of women in social, economic and cultural development, the number of China's female S&T workers has rapidly increased. In recent years, China has made significant progress in promoting educational equity for women and for their participation in S&T activities, and a large number of women are actively involved in all aspects of S&T work.

2.1 The proportion of female S&T workers keeps increasing, reaching over 50% of all high-level S&T workers

As of 2019, the total number of female S&T workers in China was approximately 39.975 million, accounting for 40.1% of all S&T workers in the country. Of these, the number of new female S&T workers meeting the professional standard reached 4.438 million in 2018–2019, accounting for 39.54% of all newly qualified S&T workers during this period. A comparative analysis of

S&T workers with different educational backgrounds shows that women accounted for more than 50% of those at postgraduate level, and that the higher the educational level, the higher the percentage of women. This is partly due to the fact that, from 2015 to 2019, the proportion of women enrolled in higher education (excluding self-taught students enrolled in continuing education) in China exceeded 53%, and remained stable for a long time. Therefore, both the number and proportion of female S&T workers in China may continue to increase in the future (CAST, 2021).

Table 1 shows that, for junior college graduates, undergraduates and postgraduates, the proportions of women were 34.15%, 40.58% and 53.30%, respectively, which suggests that the higher the level of education, the higher the proportion of female S&T workers and the more prominent their contribution. Discipline-wise, according to a survey by the Chinese Academy of Education Sciences (CAES), in 2017, the proportions of female undergraduates in science, engineering, agriculture, medicine, management, economics, law and education were 49.9%, 29.9%, 53.4%, 59.6%, 64.9%, 62.7%, 61.3% and 66.5%, respectively. In 2018–2019, China trained a total of 2.313 million female undergraduates in S&T, accounting for 40.58% of all undergraduates in S&T added in those two years. As this data suggests, the proportion of female undergraduates in S&T was significantly higher in the humanities and social sciences than in the natural sciences. That said, the overall proportion of females among all S&T undergraduates has increased, although further improvement is needed.

One of the core factors in the steady increase in the influence of female S&T workers is the increasing proportion of women enrolled in higher education.

Table 1. Numbers and proportions of newly qualified female S&T workers, 2018–2019.

Educational background	Newly qualified female S&T workers	Newly qualified S&T workers	Proportion of women
Junior college	1,462,000	4,281,000	34.15%
Undergraduate	2,313,000	5,700,000	40.58%
Postgraduate	663,000	1,244,000	53.30%
Total	4,438,000	11,224,000	39.54%

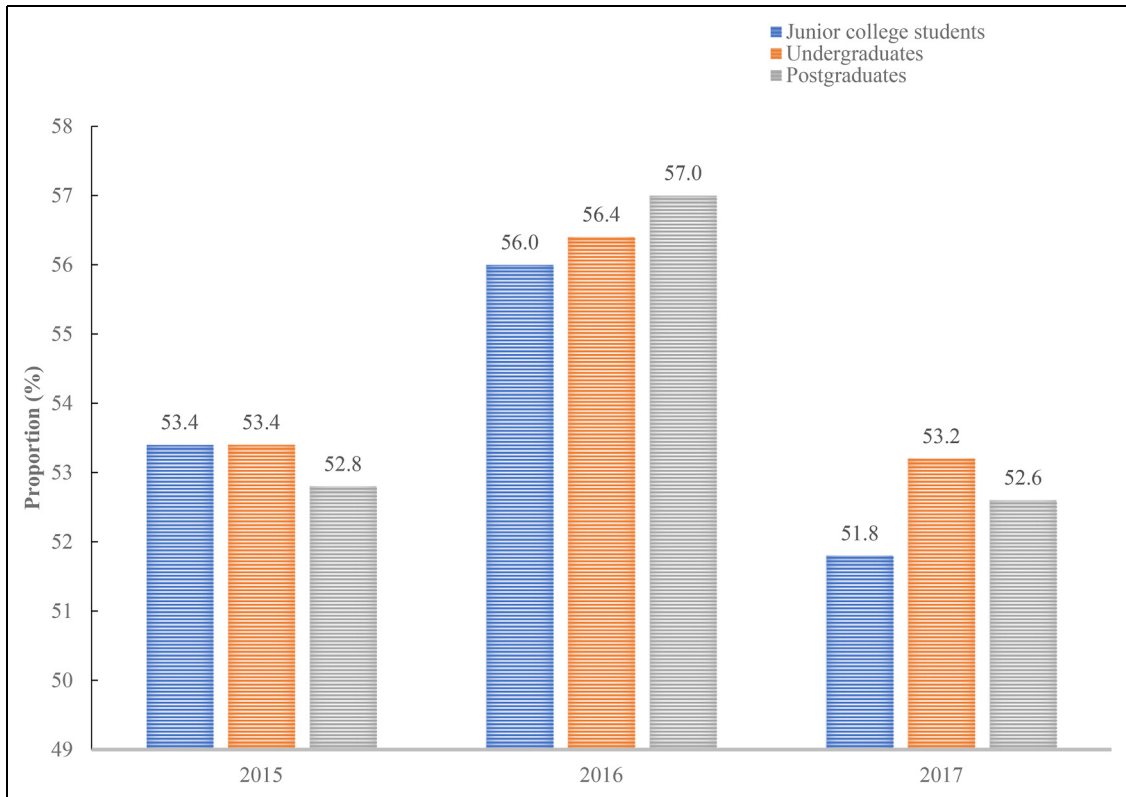


Figure 1. Proportions of female students enrolled through college entrance examinations in China, 2015–2017.

Figure 1 shows that the percentage of women enrolled in higher education in China remained above 54% between 2015 and 2017, at 54.5% in 2015, 54.8% in 2016 and 54.7% in 2017. Especially at the undergraduate level, the proportion of women enrolling exceeded 56% (CAST, 2020). Thus, it can be predicted that the total number of female S&T workers and their proportion in the S&T workforce in China will continue to increase in the future, and they will make valuable contributions to STI and S&T progress.

2.2 Chinese women have more opportunities to engage in higher education, close to the levels of developed Western countries

The main source of S&T workers in China is higher education institutions. Therefore, the total number of female S&T workers and their proportion can be obtained from the number and proportion of higher education female graduates. As the available data

shows, the proportion of women graduating from higher education institutions in developed countries exceeds 50%. According to the latest available data for higher education graduates in 2017, the proportion of such women in Sweden (62.2%) is the highest in the world. The percentages for Belgium and the United States (59.7% and 58.4%, respectively) rank in second and third places. China, with a proportion of 53.4%, ranking in ninth place, has surpassed those of the Republic of Korea (South Korea), Germany, Japan, Switzerland and other developed countries (Table 2). From this, we can see that China is already an international frontrunner in terms of women's access to higher education, and female S&T workers have become an indispensable part of S&T resources in China.

According to the data in Table 2, at the junior college level, the proportion of women is the highest in Belgium (88.6%), followed by Switzerland (71.9%). China, with a proportion of

52.2%, has surpassed that of France and is 12th on the list. At the undergraduate level, Sweden has the highest proportion (68.3%), followed by France (62.0%). China ranks ninth, with 55.0%, overtaking South Korea, Germany, Japan and Switzerland. At the postgraduate level, the United Kingdom ranks first, with a proportion of 59.7%, followed by Sweden (59.4%). China (53.3%) has overtaken South Korea, Switzerland and Japan. At the PhD level, the United States has the highest proportion (50.2%); Australia ranks second (49.9%); China (39.3%) ranks higher than South Korea (37.6%) and Japan (30.5%).

In 2016–2017, 96.8% of China's S&T undergraduates were trained in core disciplines, and science, engineering, agriculture and medicine graduates were the primary source of newly qualified S&T undergraduates. As Table 3 shows, in 2017, women accounted for 66.9% of all core S&T workers at the undergraduate level in Sweden, and the proportions of women S&T undergraduates in countries including Australia, the United States, the Netherlands, France, Canada, Belgium and the United Kingdom all exceeded 50%. Compared to countries such as Belgium, which had a proportion of 58.9%, China's proportion (40.4%) trailed well behind, but was still higher than those of

Table 2. Proportions of women with different educational backgrounds in selected countries, 2017 (%).

Country	Junior college	Undergraduate	Postgraduate	PhD	Total
Sweden	53.7	68.3	59.4	45.2	62.2
Belgium	88.6	61.4	55.8	44.0	59.7
United States	60.8	57.3	58.8	50.2	58.4
Canada	55.1	59.6	56.6	47.1	57.2
Australia	60.6	59.0	53.8	49.9	57.8
United Kingdom	57.6	57.1	59.7	46.9	57.6
Netherlands	55.2	56.3	56.4	47.9	56.1
France	51.4	62.0	55.2	45.2	56.3
China	52.2	55.0	53.3	39.3	53.4
Germany	62.4	50.8	52.4	44.8	51.1
South Korea	54.5	50.2	51.4	37.6	51.3
Japan	62.2	46.2	33.9	30.5	49.7
Switzerland	71.9	48.4	49.1	44.8	48.5

Table 3. Proportions of female S&T undergraduates trained in core disciplines in selected countries, 2017 (%).

Country	Science	Engineering	Agricultural science	Medicine	Total
Sweden	55.9	36.4	70.2	85.4	66.9
Australia	51.9	21.2	64.2	75.6	56.8
United States	54.3	21.4	53.8	84.9	55.9
Netherlands	45.1	17.4	54.0	78.4	55.5
France	53.0	26.2	47.6	82.6	56.8
Canada	56.4	22.0	58.8	77.2	53.0
Belgium	36.4	17.9	60.5	78.9	58.9
United Kingdom	53.5	18.8	70.4	76.8	51.4
Switzerland	41.1	12.3	29.0	77.2	42.1
South Korea	50.0	24.3	44.7	72.1	41.1
China	49.9	29.9	53.4	59.6	40.4
Japan	27.8	14.0	44.9	71.6	32.6
Germany	46.0	19.4	28.9	80.9	31.1

Japan and Germany. The situation of various countries is not the same in different disciplines. In disciplines such as science, engineering, agriculture and medicine, the proportion of female S&T workers was relatively low in all countries. In the case of China, the proportion was less than 30%, but still higher than those of most developed countries (CAST, 2020).

The statistics for each country show that the higher the proportion of women in higher education, the more important will be the role they play in the social arena. As shown in Figure 2, at the postgraduate level in 2017, Finland had the highest proportion of female S&T workers (58.6%), the United Kingdom ranked in second place (58.3%), and China had also crossed the 50% benchmark, with a proportion of 51.9%. This shows that China was on par with most developed countries in terms of the proportion of women receiving higher education at postgraduate level, all of which were above 50%, and was higher than those of South Korea, Switzerland and Japan.

2.3 Both the absolute number and the relative proportion of female teachers are steadily increasing

According to the 2015–2020 statistics provided by the *Education Statistics: Yearbook of China* (Ministry of Education, 2015–2020), the overall number of female full-time teachers in general higher education institutions is on an upward trend. From 2015 to 2020, the proportion of women working as full-time teachers in colleges and universities rose from 48.6% to 51.2%, crossing the 50% benchmark and surpassing the number of male full-time teachers (Figure 3).

In 2020, women made up 48.92% of all full-time teachers in undergraduate institutions, and 56.48% in higher vocational (junior college) institutions. It is noteworthy that the proportion of female full-time teachers in higher vocational colleges had already surpassed 50% (50.26%) in 2011.

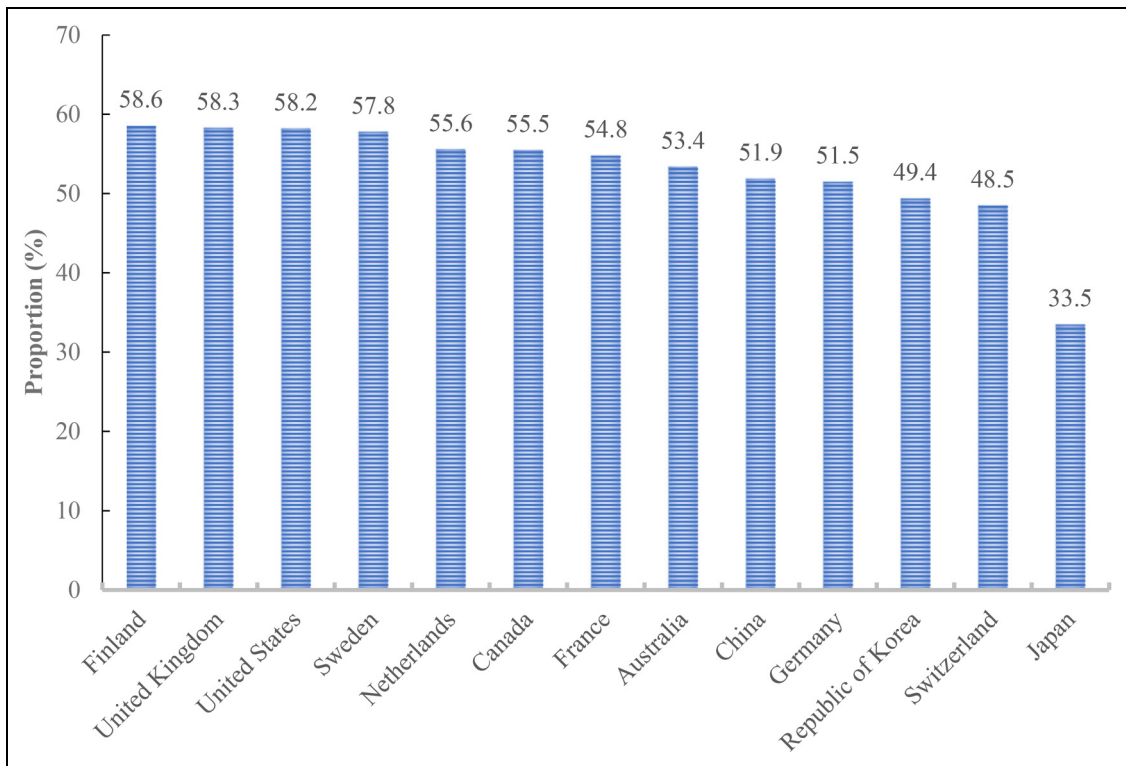


Figure 2. Percentages of female postgraduates in S&T in selected countries, 2017.

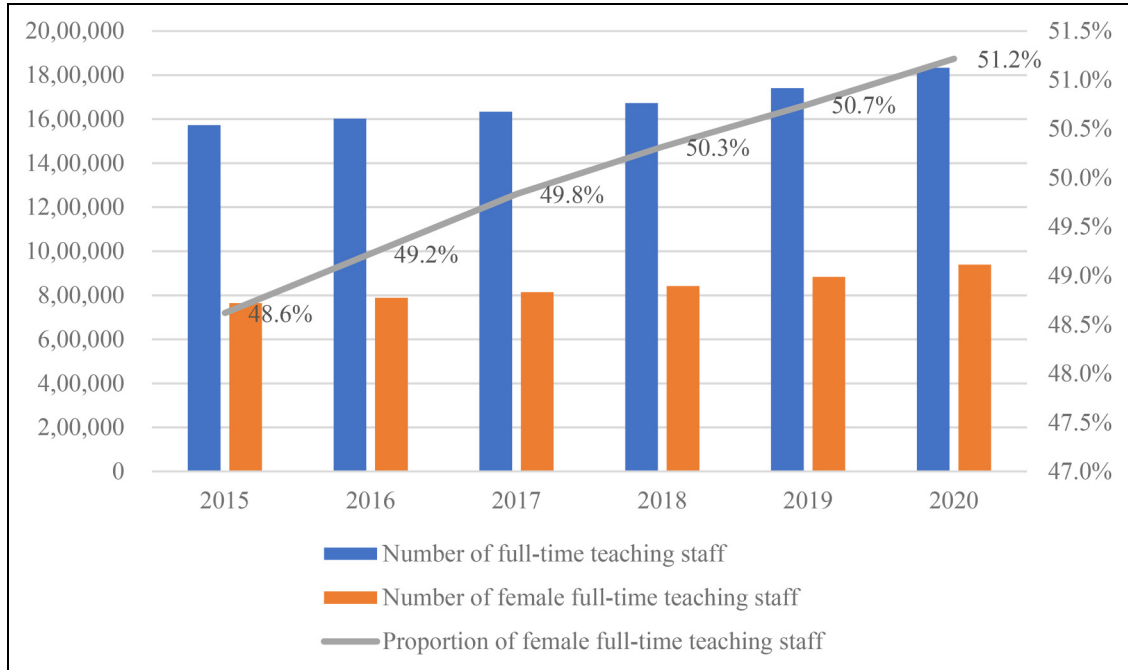


Figure 3. Numbers of female full-time teachers in general colleges and universities. Source: Ministry of Education (2015–2020).

In terms of full-time teachers in colleges and universities, there were more male than female teachers over 40 years old, while the proportion of female teachers was higher in the group of teachers younger than 40 years old. In addition, the proportion of female teachers was 55% in the 35–39-year age group, 57% in the 30–34-year age group, and 64% in the 29-year and younger age group. The proportion of female teachers increased with decreasing age.

The overall academic level of full-time teachers in China's colleges and universities is increasing steadily year on year. In particular, the number of female full-time teachers with senior academic degrees, such as PhDs and master's degrees, has increased significantly, and the number of those with PhDs has grown the fastest. In 2020, that number increased by 62% compared with 2015, and the number of those with master's degrees increased by 30%. Most female full-time teachers hold either a bachelor's or a master's degree. The number of those with a bachelor's degree remained stable up to 2019 and increased by a modest 3% in 2020.

2.4 Female full-time teachers with intermediate titles make up a significant share, but with significant variations between different levels

As shown in Figure 4, the hierarchical structure of female full-time teachers in higher education institutions follows a normal distribution (bell curve): larger in the middle and smaller at each end. According to the statistics for 2015–2020, the number of full-time teachers with intermediate titles made up the largest share and increased year on year, with the total number surpassing 2 million in 2020; full-time teachers with associate senior titles made up the second largest group and also registered the second fastest growth, with the total number surpassing 1.4 million in 2020; the increase in the number of female full-time teachers with senior titles was not significant, with the total number of those holding senior titles reaching 400,000 in 2020. The number of full-time teachers with junior and unclassified titles was relatively small, and the number of those without professional titles was the smallest.

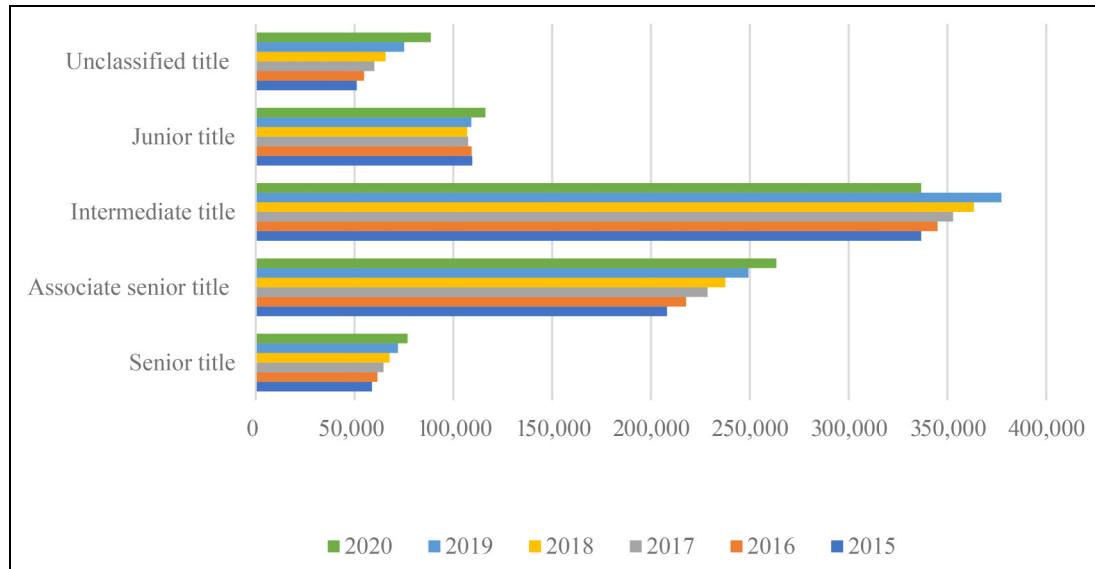


Figure 4. Numbers of female full-time teachers holding different professional titles in higher learning institutions. Source: Ministry of Education (2015–2020).

Figure 5 shows the proportion of female full-time teachers holding various professional titles in general colleges and universities. Between 2015 and 2019, the proportion of female full-time teachers with intermediate titles, which was the largest group, stayed above 40%, before dropping to 38% in 2020. The proportion of female full-time teachers with associate senior titles was more than 27%, which made it the second largest group; the proportion with junior titles was more than 13%; and the proportion with senior and undefined titles was between 7% and 10%. These figures show that there are notable gaps between the numbers of teachers at different levels. They also serve as proof of the ‘bell-shaped’ distribution of female teachers with different titles, showing that the backbone of the female teaching workforce is strong, but needs to be strengthened at higher levels to secure a more prominent contribution from female teachers (Liang, 2018).

3. Visibility of and contributions by female S&T workers in China

With the implementation of the Chinese government’s reform and opening-up strategy, female

S&T workers have become more active in the field of natural sciences, and the number of senior female researchers is continuously increasing. As China steps up investment in education and pays more attention to women’s education, the number of women scientists is steadily increasing. Moreover, in the list of S&T awards, the names of women scientists are appearing more frequently. On the one hand, this shows that women scientists are playing an increasingly important leading role in the field of S&T and making outstanding contributions to the progress and development of S&T generally; on the other hand, it reflects the gender balance in the development of S&T in China, giving fuller recognition and attention to women scientists, and providing a fairer and more just and open evaluation environment and a wider upward trajectory for women’s career development (Xue, 2021).

3.1 The total number of award-winning women scientists is steadily increasing, but the overall proportion is still relatively low

The award-winning statistics for women scientists in respect of S&T awards, scientific programmes and

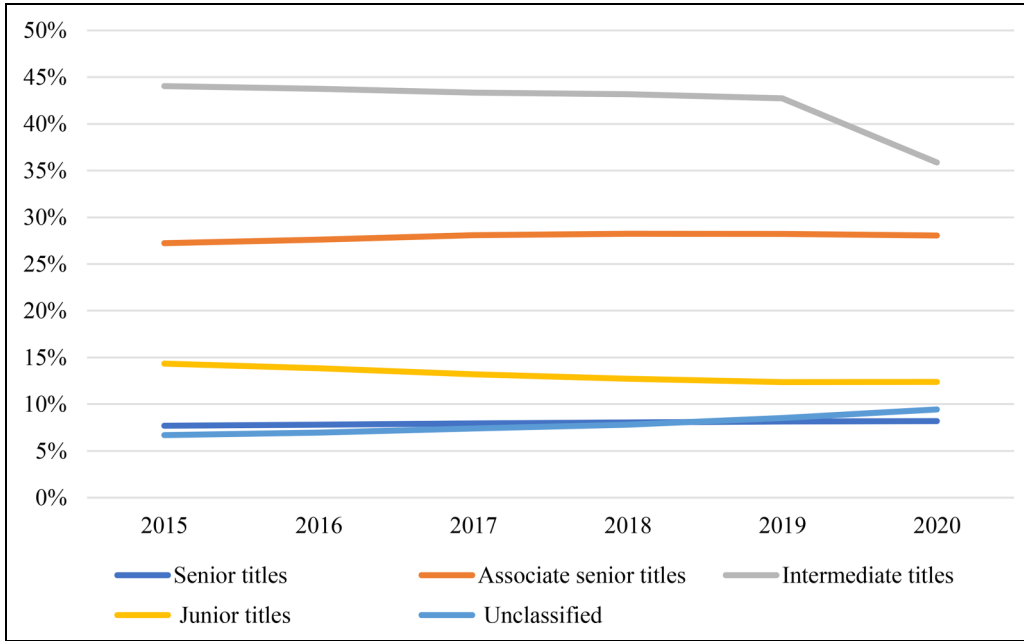


Figure 5. Proportions of female full-time teachers holding different professional titles in general higher education institutions. Source: Ministry of Education (2015–2020).

honorary titles in China have kept increasing, which reflects, to a certain degree, women's level of activity in and contribution to the field of S&T both at home and abroad.

(I) National science and technology awards

There are five prestigious national awards in the field of Chinese S&T, all established by the State Council: the National Top Science and Technology Award, the National Natural Science Award, the National Technology Invention Award, the National Science and Technology Progress Award, and the International Science and Technology Cooperation Award.

National Top Science and Technology Award. Only two people may receive the National Top Science and Technology Award each year, few of whom are women scientists. In 2016, Tu Youyou became the first and only woman scientist to win this award, the award winners in other years all being male.

National Natural Science Award. The winners of the National Natural Science Award are approved by the State Council. The first prize of the award is the highest national award in the field of natural

sciences. On average, there are approximately 20 female winners of the National Natural Science Award each year. For example, the number of female winners was 23 in 2016, but dropped to 13 in 2017. In 2018 and 2019, the numbers of female winners were 21 and 22, respectively, and, in 2020, the number jumped to 27 (Figure 6(a)).

National Technology Invention Award. Established in 1979, the National Technology Invention Award is an important award that recognizes and rewards scientists who have made outstanding contributions to technology in China. In 2016, 25 women scientists received this award. In 2017, the number dropped slightly to 22; in 2018 and 2019, the numbers were, respectively, 26 and 23. In 2020, 30 women scientists received the award, showing a moderate upward trend (Figure 6(b)).

National Science and Technology Progress Award. The National Science and Technology Progress Award covers multiple fields and, based on the nature of the projects, can be divided into four major categories: technology development, social

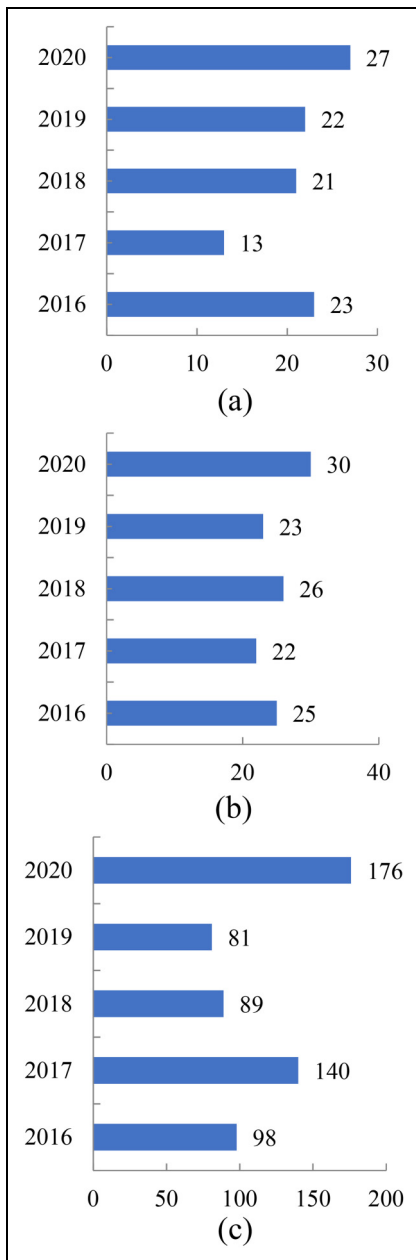


Figure 6. Numbers of women scientists receiving the various national science and technology awards, 2016–2020. (a) National Natural Science Award. (b) National Technology Invention Award. (c) National Science and Technology Progress Award.

welfare, national security, and major engineering projects. Compared with the other national awards,

the National Science and Technology Progress Award has a larger base of award-winners, which gives women scientists a greater chance to receive this award. The numbers of women scientists receiving the National Science and Technology Progress Award from 2016 to 2020 were, respectively, 98, 140, 89, 81 and 176. The doubling of the number of female award-winners in 2020 was a major breakthrough (Figure 6(c)).

International Science and Technology Cooperation Award. Katharina Kohse-Höinghaus was the only women scientist to receive the International S&T Cooperation Award of the People’s Republic of China in 2016. In 2020, there was also only one woman scientist among the award winners: Suzanne Y O’Reilly from Australia.

(2) Guanhua Engineering Science and Technology Award

The Guanhua Engineering Science and Technology Award is the highest award open to the public in the field of engineering in China. Established by the Chinese Academy of Engineering (CAE), the award honours Chinese scientists who have made outstanding contributions to and achievements in the field of engineering technology and engineering management. The award is given once every two years, in three categories: Achievement Award, Engineering Award and Youth Award. Only one woman scientist received the award in 2012, two in 2014, and six in 2016. In 2018, the number dropped slightly, when only four women scientists received the award. Thereafter, the number of female award winners fluctuated, with one and four women scientists awarded, respectively, in 2020 and 2022 (Figure 7). In general, the number of women scientists receiving the Guanhua Engineering Science and Technology Award is on an upward trajectory, which corresponds to the growing proportion of female S&T award winners.

(3) National Outstanding Young Scientists Fund

The National Outstanding Young Scientists Fund was established in order to encourage young Chinese scholars working in China’s mainland to engage in basic research in the natural sciences by providing them with research grants of between

800,000 and 1 million *yuan*. Applications to the fund are reviewed annually and, every year, approximately 25 women scientists receive the award. The number of female award winners was the lowest (15) in 2015 and highest (38) in 2019, before dropping to 30 in 2020 (Figure 8(a)).

The proportion of women scientists awarded a grant by the National Outstanding Young Scientists Fund is on a downward trajectory. Even in the peak year, the proportion was just 15%, and, at the lowest point in 2020, the proportion dropped to a mere 10% (Figure 8(b)).

(4) Honours as academicians of the Chinese Academy of Sciences (CAS) and the CAE

In addition to the above-mentioned awards and material rewards, the titles of ‘Academician of the CAS’ and ‘Academician of the CAE’ are another form of collective recognition by the Chinese scientific community that can highlight the contribution of scientists. The selection of academicians is conducted every two years. Figure 9(a) shows the number of female academicians of the CAS or of the CAE between 2011 and 2021. In terms of total size, the number of women scientists with the title of academician increased steadily during this period, but with visible fluctuations. Taking CAS academicians as an example, only one woman scientist was selected in 2011, two women

scientists were selected in 2013, and nine were selected in 2015. While the number of newly selected female academicians reached 20 in 2017, it then dropped to six in 2019. Among the CAS members, the proportion of females was 5.6%; among the CAE members, the proportion of females was 4.8%. By 2019, the proportion of female academicians had reached 9.38% in CAS and 5.33% in CAE (Figure 9(b)). In the field of high-end talent, the proportion of women was much lower than that of men. In general, the proportion of female S&T professionals remains low, and, the higher up the ladder, the lower the percentage of women. This shows that the relative absence of elite women scientists remains a problem to be rectified.

In addition to the above awards, talent programmes and honorary titles recognizing the outstanding contribution of scientists, China has also established a series of other awards, such as the Excellent Young Scientists Programme; the Young Top Talents Programme; the One Thousand Outstanding Young Scientists Programme; the Young Chang Jiang Scholars Programme; the Hundred, Thousand, Ten Thousand Talents Project; the Four Groups of Talents Project; the Pioneers of Ten Thousand Talents Programme, and the Chang Jiang Scholars Programme. However, the proportions of women scientists who are part of these programmes are still relatively low.

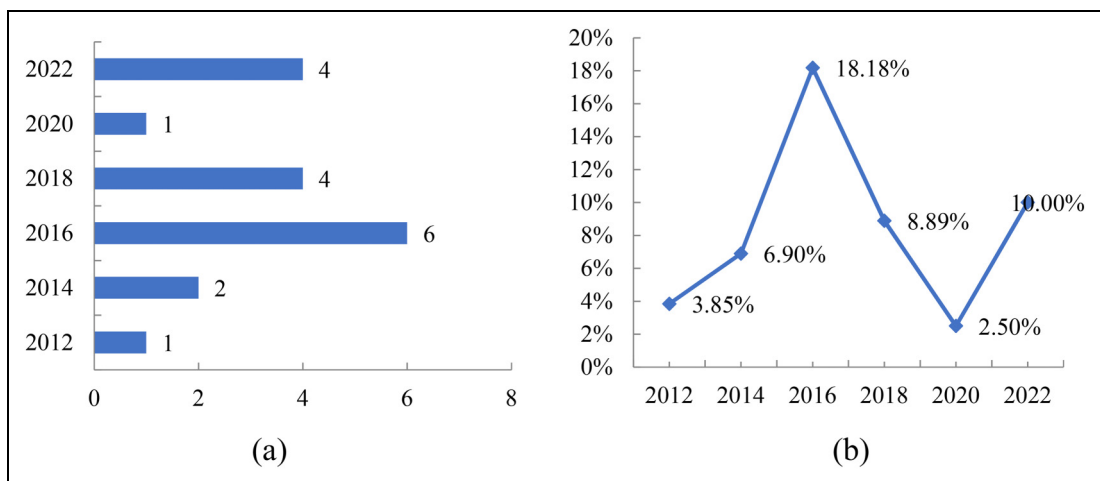


Figure 7. Numbers and proportions of women scientists awarded the Guanghua Engineering Science and Technology Award, 2012–2022. (a) Numbers of award winners. (b) Percentages of award winners.

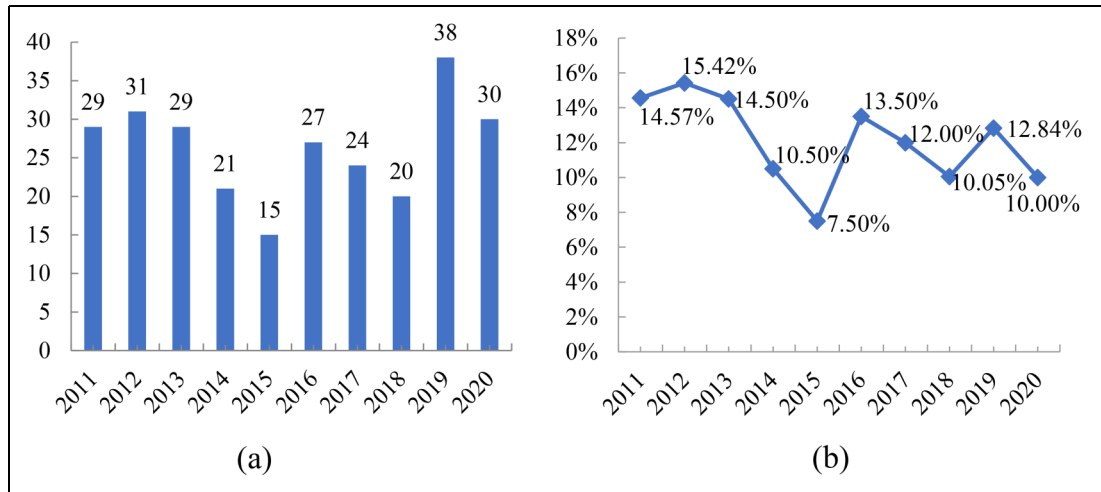


Figure 8. Numbers and proportions of women scientists awarded grants by the National Outstanding Young Scientists Fund, 2011–2022. (a) Numbers of award winners. (b) Percentages of award winners.

The gender ratio of high-level experts may not fully reflect the status of women in the natural sciences community, but the underrepresentation of female S&T professionals remains an undeniable fact. This shows that the number of places available to women scientists in the S&T community still needs to be increased, and more efforts are needed in terms of policies and system structure, social atmosphere and education, and women's own ability to provide greater space for women's growth and development.

3.2. Women scientists are gradually expanding their fields of research and making greater contributions in China

The outstanding contributions of women to scientific research have fully proven that women researchers are an important force driving S&T progress in China and are an important part of the country's S&T workforce. Both the development of society and science and the building of a country with strong S&T resources need greater participation by women researchers. A number of outstanding women scientists and S&T workers have been awarded the title of 'Pioneers of the 40th Anniversary of Reform and Opening-up' and the Medal of the Republic on the 70th Anniversary of

the Founding of the People's Republic, and they have made significant achievements in major areas of STI, such as the Tiangong space station, the Jiaolong submarine, the Tianyan surveillance satellite, the Wukong dark matter particle explorer and the Micius satellite and large aircraft, as well as in the construction of key infrastructure and industrial projects, such as high-speed rail and oil exploration (Xiang, 2022). Women accounted for more than 60% of all front-line Chinese S&T workers fighting COVID-19, and, among the 42,000-plus medical workers sent to Hubei Province to support the local pandemic response, more than two-thirds were women. Thus, female S&T workers have played a crucial role in the battle against the pandemic.

4. The international influence of female Chinese S&T workers

As more attention is paid to female S&T workers, the proportion of women receiving scientific training has substantially increased, and they have gradually become the driving force for the development of S&T in China. At the same time, female S&T workers have gradually moved to the centre stage of the international arena and are building their global influence there.

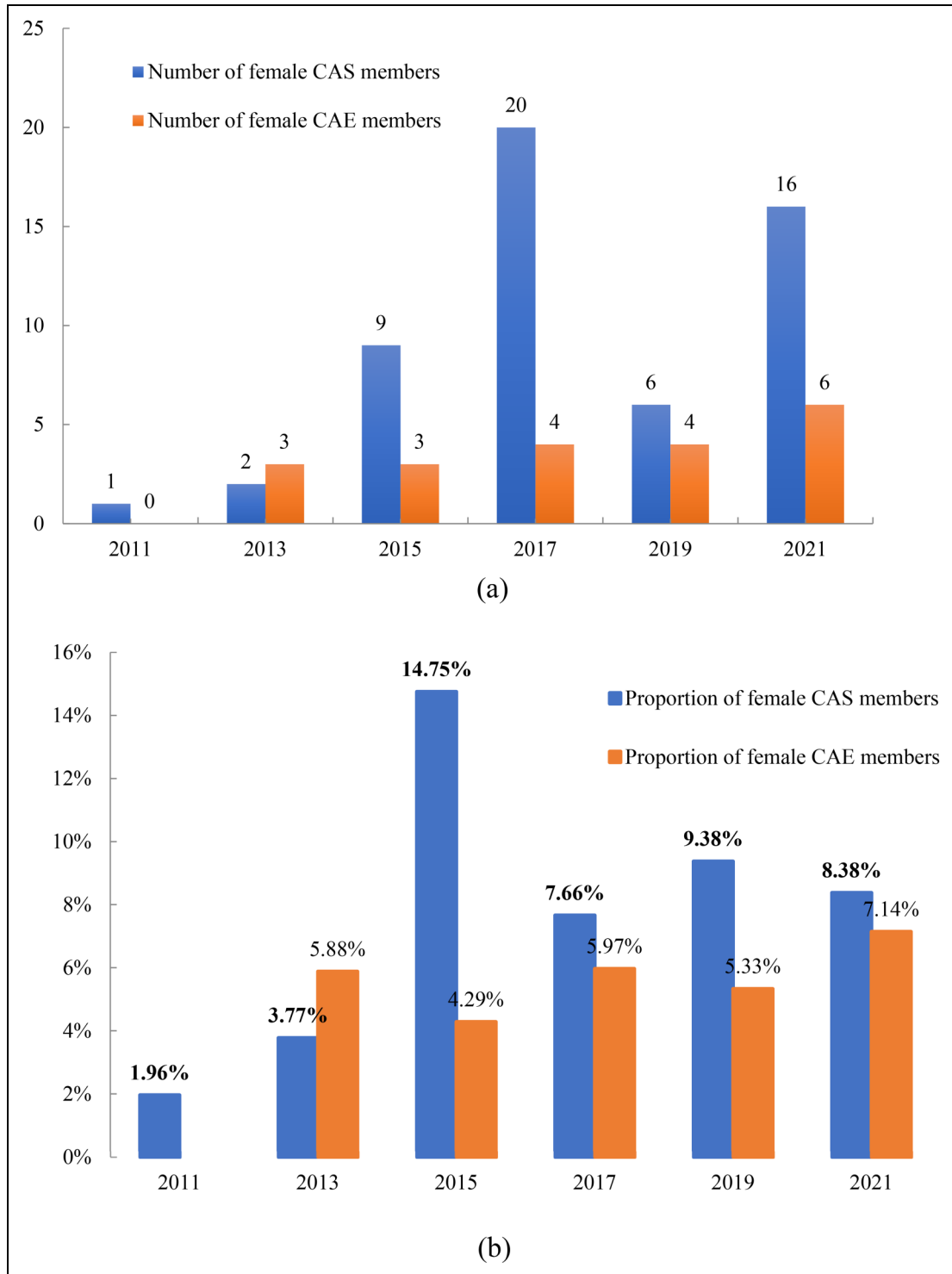


Figure 9. Numbers and proportions of female CAS and CAE academicians, 2011–2021. (a) Numbers of academicians. (b) Percentages of academicians.

4.1 Female S&T workers are active in international organizations

The China Association for Science and Technology (CAST) and its national societies have actively organized forums and academic activities for women scientists at major academic events. Through these activities, especially women's forums at international academic conferences, more and more young and middle-aged women scientists have gained avenues and opportunities to walk onto the world stage of S&T, especially to serve in international organizations.

According to the 2019 statistics for CAST personnel holding positions above executive committee member and concurrently serving in international organizations, a total of 359 people joined international organizations, including 304 men (84.68%) and 55 women (15.32%). This shows that, although female workers have some influence in the international arena, they are less active compared to men, and their relative proportion still needs to be improved. Among the female S&T workers at CAST who concurrently serve in international organizations, the proportion of those at the presidium member level was 14.69%, 15.64% for those at the executive committee member level, and 15.14% for those at the society member level (53 people). This shows that, while CAST personnel who also served in international organizations were predominantly male, females also occupied important positions, and they were active and highly appreciated by the international organizations.

4.2 Female S&T workers occupy an important place with respect to international awards

As of 2021, the L'Oréal-UNESCO for Women in Science Awards, created in 1998 to recognize the outstanding achievements of women scientists, has been awarded 23 times. Each year, five scientists receive this award globally. To date, six Chinese women scientists (Li Fanghua, Ye Yuru, Ren Yonghua, Xie Yi, Chen Hualan and Zhang Miman) have received this award (Cai, 2021). They have demonstrated the unique strengths of women scientists, inspired their peers by the power of example, and made outstanding contributions to the building of China as an innovative country.

4.3 Female S&T workers have become more actively involved in international exchanges and have gained growing international visibility

In recent years, the Chinese Ministry of Science and Technology has sent female S&T workers and young people to foreign countries to study and for training and international exchanges through such channels as the China-US Science and Technology Personnel Exchange Program, the Chinese Young Scientists Visiting the US Program, the China-US Young Scientist Forum, the China-Australia Young Scientist Exchange Program, the Japan International Cooperation Agency (JICA) training and assistance projects, the China-ASEAN (Association of Southeast Asian Nations) Science and Technology Week and the China-Italy Training Course on Environmental Management and Sustainable Development. These activities have greatly expanded the international horizon and influence of female Chinese S&T workers (Shi, 2021).

The solidarity and collaboration shown by organizations representing women researchers have steadily advanced their presence in and contributions to the field of science. The most classic examples are the establishment of the Special Committee for Women Science and Technology Workers as part of CAST's standing committee and the creation of the China Women's Association for Science and Technology. These two organizations have jointly planned and compiled a book series, *Great Beauty: Chinese Women Scientists*, which is both a testimony to the growing experience of outstanding women scientists in China and an appeal by the older generation of women scientists to younger Chinese women to join the cause of S&T development, to promote social progress with the power of technology and to fulfil their own goals.

5. Challenges and inadequacies faced by female S&T workers in China

In the fourth national survey of the status of China's S&T workers in 2017, female S&T workers became an important research subject. According to the final results, the enthusiasm and achievements of female S&T workers in scientific research have increased,

but, compared to men, their research output is still lower, their professional voice is weaker, and their status needs to be further strengthened.

5.1 Female S&T workers produce lower research output than men

According to the *Report of the Fourth National Survey of the Status of Science and Technology Workers* in 2017, 44.8% of female S&T workers had published papers in academic journals in the three years before the survey, 13.0% had registered patents, and 28.0% of the women engaged in research and development (R&D) activities had applied their research results to commercial applications. However, the proportions for male S&T workers were, respectively, 5.7, 10.0 and 16.5 percentage points higher for these three activities. In terms of scientific projects, 57.8% of the surveyed female S&T workers who had engaged in R&D in the three years before the survey had had the opportunity to undertake (either in a leading or a participatory role) scientific research projects, which was 5.2 percentage points lower than the proportion of men. Among female S&T workers who had undertaken research projects, 56.8% believed that they had had few opportunities to lead the projects. This shows that women have fewer opportunities to undertake scientific research projects and produce fewer scientific research results than men.

5.2 Female S&T workers have shorter working hours than men

In terms of time available for research, female S&T workers have less time than men. According to the survey data, 51.4% of the female S&T workers questioned believed that they did not have enough time at their disposal for scientific research, while only 44.8% of the male respondents gave the same answer. Moreover, in terms of working hours, male S&T workers had 51.0 h per week, while women had 2.7 h less. In addition, married women had 1.1 h less time than unmarried women, while married men had 1.1 h more time than unmarried men each week. It can be seen that marriage becomes an important factor affecting the working hours of S&T workers of different genders, and,

compared to the men, women work fewer hours on research due to the constraints imposed by marriage.

5.3 Female S&T workers have fewer development opportunities than men

In terms of career paths, first, at the stage of career selection, 31.7% of the female S&T workers surveyed reported experience of gender discrimination when choosing their jobs. Second, at the stage of career development, 33.3% of the female S&T workers believed that female researchers had not been given enough importance, which they saw as a serious problem. On the one hand, in terms of further education and training, 77.7% of the male S&T workers surveyed believed that they needed further education or training at this stage, while the proportion of female S&T workers who agreed with this view was higher than the proportion of men. However, more than 50% of them said they did not have the conditions to pursue that goal, and 47.2% said that their employer did not provide further education or training opportunities, which was higher than for male respondents. On the other hand, in terms of academic exchanges, 39.6% of the female S&T workers had attended academic conferences in the year before the survey, compared with 43.4% of male scientists. Moreover, 49.6% of the women scientists reported difficulties in attending academic conferences, while the proportion for males was 4.2 percentage points lower. Third, at the stage of career promotion, 21.3% of the female S&T workers reported experience of gender discrimination in relation to promotion. Most women said that, either from intermediate to associate senior title or from associate senior to senior title, they would always get promoted one year later than men. As to the question of whether they were motivated to pursue STI, only 15.8% of the female respondents said yes, which was lower than that of men (24.5%) (Yu et al., 2018).

5.4 Female S&T workers have a weaker voice

The voice of female S&T workers in the decision-making process of S&T activities is not sufficiently strong. For example, from 2010 to 2017, the proportion of female experts sitting on the National Natural Science Foundation judging panel was only 13.3%, and

only 13.4% of the directors of CAST's national societies in 2016 were women. Compared to men, the proportion of women eligible to receive funding support was much lower. For example, from 2011 to 2017, the average proportions of women receiving funding for the general and priority projects of the Young Scientists Fund were 23.4% and 10.5%, respectively. In addition, the proportion of women receiving S&T awards was also relatively low. For example, the proportions of women receiving the National Natural Science Award, the National Technology Invention Award and the National Science and Technology Progress Award were relatively low. Moreover, the proportions of women from CAS and CAE academicians, the 'Chang Jiang scholars' (only 3.9%) and international organizations were also quite low, and female S&T workers were much less active than males in the international arena, which is a clear indication of the underrepresentation and limited voice of women in the higher echelons of the S&T community.

5.5 The impact of pregnancy and nursing on the career development of female S&T workers is more prominent than it is for men

The proportion of women with experience of higher education has increased significantly, reaching 51.2% and 40.4%, respectively, for female master's and PhD degrees by 2018. The time when women graduate from a master's or PhD programme, which happens also to be the beginning of their S&T careers, coincides with their optimal period for childbirth and breastfeeding. Moreover, due to the constraints of the postdoctoral system and the promotion-or-go system implemented by some universities, giving birth during studies, delaying childbirth or giving up parenthood altogether have become the helpless choices of many female S&T workers. For female S&T workers who give birth normally, the pressure of professional competition is not reduced, and they may also face the risk of losing their accrued advantage in their career development following childbirth. Despite China's implementation of second- and third-child policies, in the absence of a fully-fledged social security system, female S&T workers remain trapped in the traditional gender division of labour, taking on more child-raising and other family responsibilities. As a result, the impact of

pregnancy and postnatal nursing periods further widens the development gap between male and female S&T workers in the later stages of their careers.

6. Policy recommendations

In 2011, the Chinese Ministry of Science and Technology and the All-China Women's Federation published the 'Opinions on strengthening the ranks of female science and technology professionals'. In the same year, the National Natural Science Foundation of China launched an initiative 'giving priority to female researchers under the same conditions in the evaluation of various projects'. Under this initiative, the age limit for female researchers eligible to apply to the Young Scientists Fund was extended from 35 years to 40 years, and, in case female researchers were unable to complete their research projects on time due to childbirth, the deadline might also be extended. In 2015, CAST published the 'Notice on playing the role of national societies to promote the growth of high-level female science and technology professionals'. In 2021, the relevant ministries and commissions further issued a series of documents relating to the support and services available for fostering female S&T professionals. For example, in April 2021, seven ministries and commissions, including the All-China Women's Federation, the Ministry of Science and Technology and CAST, jointly formulated the 'Opinions on implementing the programme of women pioneers in science, technology and innovation', and, in July, 13 government departments and institutions, including the Ministry of Science and Technology, the All-China Women's Federation and CAST, jointly issued the 'Measures to support female professionals in science, technology and innovation'.

Recently, the Chinese government has introduced some pro-women policies to promote the development of female S&T workers, which have boosted the development of female S&T workers and have received positive responses. That said, to ensure that women can better play their proper role in scientific research, there is still room for improvement in terms of cultural concepts, the external environment, policy systems and award design (Xu, 2021). In the future, we must continue to pool the efforts of the whole of society to provide more practical guarantees for women to participate in academic exchanges and research activities, and thereby shape a broader space for development.

6.1 The administrative departments of the S&T industry, as well as corporate and public research institutions, should create conditions to establish a more humanistic working environment

The S&T community, the public and social media should give more attention to female S&T workers, thereby helping to expand and enhance the latter's influence. In constructing the expert pool of national S&T awards and selecting and appointing judges, the proportion of female experts should be further increased in order to give women a greater voice in the scientific decision-making process. We should strengthen continuing education for women in S&T, provide more opportunities for female S&T workers to participate in continuing education and training activities organized by various government departments and establish special talent programmes for women working in the field of S&T. In the evaluation of research projects, the gender dimension could be included as a factor in order to increase gender diversity in the composition of the research workforce. We should encourage research institutions to create a fairer development environment for female S&T workers, further strengthen the monitoring and supervision mechanisms for employment discrimination, provide equal opportunities for women in promotion, training and academic exchange, and implement the principle of 'priority for women under equal conditions'.

6.2 There is a need to respect women's contribution to society through childbirth and to help female S&T workers balance family and career planning

We should provide effective policies for female S&T workers during pregnancy and postnatal nursing to ensure that their rights and interests in scientific research activities are protected, especially during the period of assessment and evaluation, title evaluation and tenure appointment, and relax the term requirements for female S&T workers during pregnancy and postnatal nursing whenever appropriate, such as by extending the assessment and evaluation period, adopting a flexible work system, and optimizing evaluation and performance assessment methods. Drawing on the experience

of the 'Restart Postdoctoral Fellowship' of the Japan Society for the Promotion of Science, we could make greater efforts to help women return to their research careers following childbirth. Labour security departments should strengthen the supervision of employers and the protection of women during pregnancy and postnatal nursing, and S&T employers should provide nursing rooms for women in need, establish their own nurseries or babysitting rooms, and provide childcare subsidies. Scientific research institutions and social service agencies should work together to encourage the provision of commercial domestic services for female S&T workers to help them strike a reasonable balance between career development and family responsibilities. Following the example of practices in other countries, we could encourage male workers to take paternity leave so as to fundamentally resolve the problem of gender discrimination caused by childbirth, strengthen men's awareness of family responsibilities, and share the burden of childcare (Bao, 2011). The government, society, enterprises and public institutions should all provide legal and policy protection and public opinion support for men to practise good fatherhood. We should take greater steps to care for the physical and mental health of women in S&T, and strengthen psychological counselling and health support for women during pregnancy and postnatal nursing. We should also encourage women in S&T to develop a correct and balanced perception of the work-family relationship, in order to build their confidence and thereby make outstanding contributions to the development of S&T in a positive space of career development created by the government.

6.3 There is a need to increase the publicity relating to the rewards available to female S&T workers and strengthen education relating to building women's self-reliance and values

We need to adopt effective publicity and policies to promote the outstanding contributions of women to S&T progress, present their stories in their pursuit of career development, and communicate their achievements to the public. This will not only serve as encouragement for female S&T workers, especially female award winners, but will also keep them motivated to pursue scientific research and augment and strengthen the S&T workforce. In addition, we should actively

expand the breadth and depth of gender-equal education, encourage and support female students to participate in S&T competitions, and take such steps as setting up scholarships for outstanding female students in S&T majors. While ensuring gender equality in S&T education, these measures might also motivate female students to build their skills and choose scientific research as a lifelong career (Shen, 2019). We should strengthen education to bolster women's confidence and self-awareness during the different stages of school education and encourage women to cultivate a positive and enterprising mindset in order to make even greater contributions to social development.

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