Heliyon 10 (2024) e33352

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Exploring influential factors in Chinese engineering professors' industrial experience: A big data and CV analysis approach

Jin Liu [a], Ilaha Balakishiyeva [b], Kaizhe Chen [b,*]

[a] School of Humanities and Social Sciences, Beijing Institute of Technology, Institute of International Dispute Prevention and Resolution, China
[b] School of Humanities and Social Sciences, Beijing Institute of Technology, Beijing, 100081, China

A R T I C L E I N F O

Keywords:
Engineering education
Engineering professors
Engineering experience
CV analysis
Resume analysis
Big data

A B S T R A C T

There is a long-standing criticism in academic circles about the inadequacy of engineering industrial experience for professors in Chinese research universities, but there is a lack of analysis of the manifestations and root causes of the problem. The research aims to contribute meaningful insights into the factors influencing the industrial experience of engineering professors in Chinese research universities, facilitating informed policymaking and fostering collaborative efforts between academia and industry. This paper examines Chinese engineering professors' industrial experience using big data mining, computing, modeling, and image rendering. The data was collected from the publicly available CVs from the websites of various Chinese universities which contains data on colleges and universities across China and analyzed engineering professors' professional trajectories and industrial experience using the method of resume analysis. A nonlinear logistic regression model is fitted to determine the impact of multiple independent variables on the probability of engineering industrial experience among professors, with logit transformation and maximum likelihood estimation. The results show that a low percentage of engineering university professors in Chinese research universities have had industry employment after obtaining their Ph.D. degrees. The regression model indicates that gender, level of inbreeding, overseas study experience, university level, and birth age significantly affect the engineering experience of professors. This study proposes several policy recommendations based on comparative analysis and its research. The study's findings are critical for policymakers to create policies that promote industrial partnerships as a fundamental aspect of the professional development of engineering faculty and for further research in the field.

1. Introduction

The primary objectives of this research endeavour are multifaceted, each aimed at comprehensively investigating and addressing the current state of engineering professors' industrial experience in Chinese research universities. First and foremost, the study seeks to assess the existing landscape by examining the prevalence and depth of industry employment among engineering professors post-Ph.D. degrees. By doing so, we aim to provide a nuanced understanding of the current state of affairs within Chinese academia.

Furthermore, the research endeavors to delve into the manifestations and root causes of the perceived inadequacy in engineering professors' industrial experience, addressing long-standing criticisms within academic circles. This analytical exploration is crucial in

* Corresponding author.
E-mail address: chenkaizhe1123@126.com (K. Chen).

https://doi.org/10.1016/j.heliyon.2024.e33352
Received 22 June 2023; Received in revised form 10 June 2024; Accepted 19 June 2024
Available online 24 June 2024

uncovering the underlying factors contributing to the observed disparities and shortcomings, thus paving the way for informed interventions.

A critical aspect of our inquiry involves the exploration and identification of factors that significantly influence the industrial experience of engineering professors. With a specific focus on gender, level of inbreeding, overseas study experience, university level, and birth age, the study aims to unravel the intricate web of variables shaping the professional trajectories of faculty members in Chinese research universities.

To facilitate a comprehensive analysis, the research leverages advanced methodologies such as big data mining, computing, modeling, and image rendering techniques. This approach allows for a detailed examination of the professional journeys of Chinese engineering professors, shedding light on the diverse pathways and experiences that shape their careers.

A key quantitative objective of the study involves the development and application of a nonlinear logistic regression model. Employing logit transformation and maximum likelihood estimation, this model aims to quantitatively assess the impact of multiple independent variables on the probability of engineering industrial experience among professors. This statistical analysis adds a quantitative dimension to our exploration, providing a robust framework for understanding the complex interplay of factors influencing industrial experience.

Drawing from the research findings and comparative analyses, the study further aims to propose policy recommendations. These recommendations, grounded in empirical evidence, are designed to address identified gaps in engineering professors' industrial experience, thereby informing policymaking for the professional development of faculty in Chinese research universities.

Beyond policy considerations, the research strives to foster collaborative efforts between academia and industry. By providing insights that promote a symbiotic relationship, the study seeks to enhance professional development avenues for engineering faculty and ensure alignment with industry needs.

Lastly, the research aims to guide future inquiries in the field by offering critical findings and recommendations. By laying a foundation for addressing broader questions related to the intersection of academia and industry in the context of engineering education, the study endeavors to contribute lasting value to the ongoing discourse in this dynamic and evolving field. Through the pursuit of these research objectives, our study aspires to provide a comprehensive and insightful contribution that transcends the boundaries of academia and resonates with policymakers, educators, and industry stakeholders alike.

1.1. Literature review

Around 30 years ago, most engineering academics were employed in relevant industries, and the engineering curriculum knowledge base hinged on the facts and approach that students required for their careers [1]. Initiatives like the envisioned "2020 engineer" propose a transformation of engineering education, aiming to align with this vision and foster innovations in uncharted engineering domains. Within this context, the primary challenge of higher education in engineering lies in equipping students to embody contemporary and efficient engineering roles. These roles encompass leading and contributing to conceptualizing, designing, implementing, and operating systems, products, and projects. Students must receive rigorous technical preparation, cultivate social responsibility, and a perpetual innovative mindset to accomplish this [2].

The essential role universities and other public research institutions assume within innovation systems is widely acknowledged. This encompasses their crucial contributions to the generation of fundamental research, the transfer of technology, and the dissemination of knowledge to enterprises [3–8,70]. University-industry collaboration (UIC) refers to the engagement between distinct components of the higher education system and industrial domains, primarily fostering knowledge and technology exchange [9]. Viewed from the academic sphere, collaboration with corporate entities embodies a strategic avenue for realizing their "third mission" [10,11].

In pursuing enhanced competitiveness, UIC emerges as a pivotal external reservoir of knowledge and technological infusion for enterprises [12]. Additionally, the physical proximity of universities assumes significance, as geographical closeness is observed to foster diverse UIC modes, thereby positively correlating with the frequency and caliber of collaborative endeavors [13–21]. Collaborations between universities and industries yield an enhanced understanding of the motivational dynamics within individual researchers [22].

While examining the relationship between industrial collaboration and academic productivity, Siegel et al. (2003) opined that any collaboration between scientific researchers, including those with fellow researchers or government officials, is positively associated with improved productivity. However, collaboration between scientific researchers and industry employers was found to have a more significant impact on productivity levels than collaborations with other scientists or government officials [23]. Lin and Bozeman (2006) reported that 41.6 % of industry researchers had private sector employment for less than three years, 28.7 % were in commercial jobs for three to nine years, and the remaining 29.8 % stayed for more than nine years. About 62 % of faculty staff had their first corporate job before completing their doctoral studies, and approximately 33 % started their industry jobs after completing their doctoral studies but before receiving tenure. Only about 5 % were employed by industry after receiving tenure [24].

Public policies may encourage collaboration between industry and academia, including staff exchange programs such as the NSF Grant Opportunities for Academic Liaison with Industry (GOALI) program. While such programs are often considered productive, research has identified various institutional obstacles hindering the development and maintenance of partnerships between scientists and industries. Employing researchers with industry backgrounds or exchanging with relevant companies may foster beneficial innovation in universities and research institutions, as highlighted by the GOALI program and various research findings. Recent studies have also identified alternative interactions between academia and industry but have shown that private sectors often prioritize their perspectives [25].

According to research conducted in Mexico by Guerrero et al. it is evident that businesses primarily leverage University-Industry Collaborations (UICs) for purposes like exploring novel knowledge, accessing resources and capabilities from universities, participating in extended-term and transformative innovation endeavors, and accessing public funding and incentives that are linked to obligatory UIC initiatives [26]. Additionally, the positive impacts of financial backing for innovation are most pronounced when firms effectively engage in collaborative ventures with universities [27].

According to Lin and Bozeman, researchers employed a dataset amalgamating curriculum vitae and survey data to discern substantial distinctions between individuals with and without prior industry experience. The investigation, utilizing a straightforward model of research productivity, delineated that academic researchers with antecedent exposure to industry exhibited a reduced count of total career publications, concurrently demonstrating heightened support for students [24].

The present study paper examines Chinese engineering professors' academic pursuits over time to fill this gap and provide empirical information. The study focuses on accounting for the industrial experience of engineering professors by analyzing their academic degrees and employment histories. Using big data sources, this neglected area of engineering education in China is explored, revealing a reality where engineering professors have limited industrial experience, leaving a gap in their engineering expertise. The study's findings are critical for policymakers to create policies that promote industrial partnerships as a fundamental aspect of the professional development of engineering professors and for further research in the field.

In the subsequent sections, this paper discusses the global trends in engineering education and the relationship between the industrial involvement of engineering professors and their professional experience. This will be followed by an explanation of the methods used for data collection and analysis. Finally, the paper will present its findings, provide an in-depth analysis of the results, and offer conclusions.

1.2. Trajectories of engineering professors and industrial experience

Many universities employ engineering faculty members to source external research funding. These academics typically hold doctorate degrees and have technical qualifications. They are responsible for teaching undergraduate and graduate courses but may not have received guidance on teaching methods. Some professors are not interested in accepting coaching to improve their teaching abilities and rely primarily on lectures. According to US Department of Education statistics for 2001, 87 % of engineering schools in the US use lectures as the primary teaching method. Professors may delegate fundamental interactions with students to teaching assistants with little technical experience or understanding of real-life engineering situations. However, engineering education requires a combination of engineering and teaching skills. Therefore, engineering professors should be trained or experienced in both fields and understand what it takes to pursue an engineering profession while facilitating student learning. Modernization of engineering education is necessary to meet the needs of today's community [28].

Some countries have implemented successful programs and policies to address concerns about the lack of industry experience among engineering faculty. In contrast to some countries, such as the US, which prioritize industrial experience for engineering faculty, engineering education system is more comprehensive. Universities in the US closely align with professors' industry backgrounds through various programs such as part-time professorships, university-industry cooperation, on-campus training, student-professor practice systems, and recruitment and evaluation programs. MIT is a leading example of this approach, emphasizing knowledge and practice in engineering education [29].

MIT's methods to improve the industrial experience of engineering professors include selecting candidates with at least one year of practical experience in industries, providing industrial experience through workshops and training classes, allowing professors to practice in industries during their vacation time, hiring experienced engineers directly from companies to teach at universities [30]. Part-time professors, who often come from industry and have rich practical experience, represent 47 % of the total staff in American universities, including MIT [31].

Germany also attaches great importance to the issue of industrial experience for professors. The German government has promulgated many decrees to regulate this system, such as the Ausbilder-Eignungsverordung (AEVO) for industry training, which guarantees the rights and status of industrial experience for professors and regulates their competence requirements [32]. German engineering colleges and universities require more than 5 years of work experience in companies for the title of professor, contributing to integrating engineering professors into the frontiers of engineering and promoting the integration of academic research and social practice. Additionally, experts from German companies are involved in faculty management, and some more prominent universities have advisory committees consisting of professionals from the business community to advise on forming disciplinary and professional curricula [33].

Imperial College London, a leading engineering university in the UK, adopts a teaching assistant system during the PhD training stage. It allows PhD students to be responsible for part of the lectures and laboratory teaching and participate in workshops and practice to improve their knowledge and experience. This system reduces the teaching capacity of current engineering faculty, allowing them to devote more time to practical training and developing the overall competence of PhD students [34].

Nanyang Technological University (NTU) in Singapore has an advanced concept in the training and evaluation of engineering faculty. The university adopts a performance-based assessment principle for professors, and the assessment weight is talent training, scientific research, and social service in a 2:2:8 ratio. NTU provides various course training and opportunities for faculty members to attend academic conferences. It recently established a $500,000 training fund in partnership with the Singapore Educational Services Union (ESU) to improve its engineering faculty's digital information application skills to meet the needs of Industry 4.0 [35].

The lack of industrial experience among Chinese engineering professors has become a significant concern, hindering the development of the country's economy and society. The quality of engineering education and the practical skills of professors are critical for career development. In 2008, Wu Qidi, the vice minister of the Ministry of Education, identified a lack of industrial experience among professors as one of the main obstacles to engineering education in China [36]. To address this issue, the Ministry of Education launched the "Education and Training Program for Excellent Engineers" in 2010 to recruit engineering professors with industrial experience [37,38]. In 2017, the "Fudan Consensus" was introduced, calling for the construction of new engineering disciplines in China and appointing "dual professors" with academic and industrial backgrounds.

Despite these policies, studies indicate that the practical skills of engineering professors in China have not improved significantly. For instance, Jin Min et al. (2014) conducted a survey showing that engineering professors prioritize academic knowledge over practical skills. In addition, many engineering professors in Chinese colleges and universities lack sufficient industrial experience [39]. Hu Xin et al. (2016) found that, in 52 colleges and universities in different regions of China, the engineering industrial experience of professors was significantly inadequate. Moreover, more professors with full-time industry work were found in "Project 211″ universities compared to "Project 985″ universities. "Project 211″ is a government initiative aimed at creating 100 top universities in China, while "Project 985″ is a specialized program to develop Chinese equivalents of Ivy League universities [40].

Scholars have identified several reasons Chinese engineering professors lack industrial experience. One reason is the criteria for recruiting, evaluating, and promoting professors, which typically prioritizes academic accomplishments and research funding over industry experience. Additionally, academic endogeny or inbreeding, a practice where universities prefer to hire their graduates, has contributed to the problem. It is essential to improve the engineering training of professors through institutional measures as a mitigation strategy to this challenge. In 2020, Zhu Zhengwei et al. (2020) analyzed the current situation of industry experience among university professors and found that only a small percentage of professors were involved in teaching, academic, and industrial practice activities simultaneously. A comparison of Tsinghua University and MIT showed that American engineering professors have more extended engineering practice at each age than their Chinese counterparts [41]. Therefore, Chinese universities must adopt effective measures to recruit and evaluate professors based on both academic and industrial backgrounds.

University-industry cooperation in China is scanty due to various factors. Firstly, most young professors are overwhelmed by academic demands such as heavy teaching loads and research tasks. Besides, they are not interested in industry practice. Moreover, an effective management system between industries and universities is yet to be formed. According to Guo Xiuyun (2013), the lack of such a system renders university-industry cooperation formal, and professors are accustomed to working behind closed doors. Consequently, scientific research results become detached from practice, and their application is not adequately valued [42]. Xu (2017) adds that the construction of government laws and regulations is not comprehensive enough, and the rights, responsibilities, and evaluation systems of relevant stakeholders are not clearly expressed when professors are sent to enterprises for training [43]. The cooperation has remained at the level of theoretical research for a long time.

In contrast, the experience of the US academia suggests that successful university-industry collaboration must support the mission of each partner. Institutional principles and national resources need to focus on bolstering appropriate and enduring partnerships. Negotiations must be streamlined, focusing on the interests of each party and working together to ensure timely research conduct and development of research products (NCURA 2006). University-industry collaborations can take several forms, from formal equity cooperation to human capital liquidity, research publications, meetings, and professional group interactions [44]. It is also helpful to distinguish between short and long-term collaborations. Short-term collaborations typically have predefined outcomes modulated through contract research, advising, and licensing. Long-term partnerships include joint projects and public-private partnerships, including privately funded university research institutes or rectors university-industry joint research centers, often allowing companies to subscribe to a set of services and specific updates regularly. Long-term collaborations are more strategic and provide a platform where companies can build on the university's skills, methods, and tools to develop more robust innovation capabilities [45].

To strengthen university-industry joint practices, specific public policies must be enacted. Public policy can affect the tendency of businesses to cooperate with universities and the extent of such cooperation in different ways. This includes direct roles in funding universities, research and development projects, and regulatory roles in influencing public rule sets. The government can also encourage cooperation through soft measures, such as regulating specific support services to companies and universities in finding collaborators and conducting outreach activities to facilitate networking and increase knowledge of the value of collaboration.

Lastly, it is paramount to strengthen engineering professors' awareness. Li Yanfeng (2013) notes that most engineering professors in China currently lack the enthusiasm to conduct industrial experience in engineering education [46]. Li Peigen (2012) further points out that theory is detached from practice, emphasizing learning over skills, and for most engineering professors in China, it seems that the brilliance of engineers is not as dazzling as that of scientists. Due to the lack of cultural traditions closely related to engineering practice, there is a lack of awe and interest in engineering technology [47].

2. Research design

There is a plethora of criticisms about the lack of industrial experience of engineering professors in China, but there is no such a glut of empirical research based on large samples. In the current study, data obtained from an extensive database of Chinese university professors' curriculum vitae (CVs) is used to analyze the data of engineering professors.

The CV is one of the most reliable resources for gaining insights into the careers of scientists and engineers. It provides crucial information about the educational background, research area, work experience, and academic affiliations in a more comprehensive and structured way. Thus, CVs contain valuable long-term data to investigate scientists' careers in detail [48].

CV analysis has been utilized to study scientists' and engineers' career paths and evaluate research accomplishments. For instance, the Research Value Mapping project has brought insightful outcomes, which have also been employed to examine their career trajectories [48] and industry collaborations [49,50].

In this research, we employed resume analysis as a fundamental method to gather data about college educators. Initially, we utilized a Python-based web crawling technique to extract data from web pages. This approach allowed us to retrieve pertinent information present on the web pages. Subsequently, we utilized the Etree library to create an object and load the extracted web page data into this object. Lastly, we applied the xpath function and a predefined xpath expression to identify specific tags and extract the required data. These consecutive steps enabled us to gather publicly available resume details of all teaching staff in professional schools across the chosen universities, thereby establishing the initial database for our study.

During the practical execution, we excluded three military educational institutions from our sample. The entire data collection process spanned three years, successfully acquiring teaching faculty resumes from 109 universities in China.

2.1. Data source

This study utilized publicly available CVs from the websites of various Chinese universities to analyze the industrial experience of engineering faculty. The sample was drawn from universities participating in the 'Project 211′ initiative, totalling more than 89,000 CVs. These CV included engineering professors' profiles across difference universities in the country. These was done to ensure a diverse representation of engineering faculty across different regions and institutional profiles. Through these our study unravels the national complexities of engineering professors in the Chinese educational system. The combination of these sources provided a comprehensive dataset of university professors in China. The CVs obtained from university websites were publicly accessible, ensuring transparency and accessibility of the data. The data include various details such as professors' names, gender, titles, subject majors, universities, years of graduation at each academic stage, and different types of work experience and institutional information before joining their current universities. For this study, the database was searched, and all engineering professors were selected, resulting in 47,275 resumes (53.12 % of the total sample size). These professor resume data were further explored and structurally analyzed to establish over ten different variables, including gender, engineering category, whether they are inbred professors, overseas study experience, interval time between different academic stages, and specific work unit status after PhD. As the engineering experience of professors in this study involves precise time division, any data with missing time information in each education stage and employment stage was strictly eliminated, resulting in 13,688 valid resume data of engineering university professors.

2.2. Variable settings

This study examined the engineering industrial experience of engineering professors by analyzing their resumes across three academic stages: 1) after bachelor's graduation to before master's enrollment, 2) after master's graduation to before doctoral enrollment, and 3) after doctoral graduation. The first two stages were used to estimate the engineering practical experience of engineering professors under a specific period by using the interval length of two academic stages. In the third stage, the specific work unit and the nature of the work were investigated and matched with the correlation between the professor's teaching discipline to determine if the professor had engineering industrial experience. However, it is worth noting that this method can only infer the possibility of industrial experience and cannot precisely determine the specific participation.

Three situations need to be considered when using this method. First, it is impossible to judge if a time gap between undergraduate-master and master-doctor periods is engaged in practical experience. Second, some university professors may have jobs unrelated to engineering practice, such as clerical jobs or primary and secondary school teaching after doctoral graduation. Third, some university professors may be engaged in engineering practice that is not entirely consistent with their disciplines after entering the university.

The independent variables in this study were the graduation years of engineering professors in the stage before doctoral studies, which ranged from 1943 to 2010 for undergraduate and 1947 to 2014 for master's degrees. Professors were divided into five graduation years to explore changes in engineering industrial experience over time. The university level was also considered as an independent variable, and the samples were divided into four levels based on national policies and social recognition.

The study also examined several factors that may impact professors' engineering industrial experience, including gender, age, academic inbreeding, and overseas study experience. There were 3112 female engineering faculty data and 10,776 male engineering faculty data in the CV database, with a male-to-female ratio of 3.46:1. The percentage of inbred professors in engineering was 42.22 %, and the percentage of engineering professors with overseas study experience was 24.28 %. All data were regressed and analyzed using R language.

2.3. Model setting

The logistic regression model is commonly used to explore the impact of dichotomous variables on an outcome. In this study, a nonlinear logistic regression model is fitted to determine the impact of multiple independent variables on the probability of engineering industrial experience among professors, with logit transformation and maximum likelihood estimation. The dependent variable is whether the professor has engineering experience, determined by their post-doctoral work experience, and is coded as 1 for those with experience and 0 for those without. The professor's year of birth is a continuous variable and does not require transformation. Gender, inbreeding, and overseas study experience are transformed into dummy variables with values of 0 and 1, and the coefficients of the dummy variables determine the impact. The levels of universities are represented by discrete multicategorical variables and are divided into four levels: Tsinghua and Peking University, C9 universities, general "Project 985″ universities, and "Project 211″ universities. Since the impact of school-level differences on the dependent variable may not be the same for adjacent levels, a dummy variable with one less than the option is used, with “Project 211″ universities as the reference level. The impact of other levels of universities on professors’ engineering industrial experience is explained by comparing them to the reference level. The probability of engineering professors having industrial experience is set as $P_{practice}$. Its value is logit transformed to take the range from (0,1) to (-∞,+∞), and the logistic regression model established for the independent and dependent variables of the appeal is as follows:

$$\text{Logit}\left(p_{practice}\right) = \ln\frac{p_{practice}}{1-p_{practice}} = \beta_0 + \beta_1 age + \beta_2 gender + \beta_3 overseas + \beta_4 inbreeding + \beta_5 university(1) + \beta_6 university(2) + \beta_7 university(3)$$

Among them, each regression coefficient βi represents the natural logarithm of the ratio between the probability of industrial experience and the probability of no process practice after the change when the corresponding independent variable changes by one unit or one state changes relative to another state. In this paper, we mainly explore whether the change in the independent variable significantly affects the probability of professors’ engineering practice and the magnitude of the effect.

2.4. Ensuring validity and reliability

This research hinges on the assumption that CVs accurately represent a professor’s career. We mitigated the biases accompanying smaller sample sizes by examining a large sample size. The large sample size was also to ensure the generalizability of the research, as it provides the lens through which we may better unpack the nuanced engineering professors’ experiences. The methodology of extracting and analyzing data using Python-based web crawling and logistic regression models is consistent with accepted practices in academic research, thus ensuring content validity. Python-based web crawlers are designed to systematically navigate the web, ensuring no relevant data is missed. The crawler would be configured to capture all pertinent details from designated sites or databases for our study of professors’ CVs. Like other automated web crawlers, Python-based scrabs retrieve the same type of data in the same manner each time, ensuring that there is no human bias or error introduced during the data collection phase.

To further ensure the reliability of the findings, the data extraction method, while automated, was cross-verified for consistency across various CVs to ensure the accuracy of the extraction process. Moreover, the logistic regression model’s fitting process was subjected to repeated tests to ensure stability and repeatability of results.

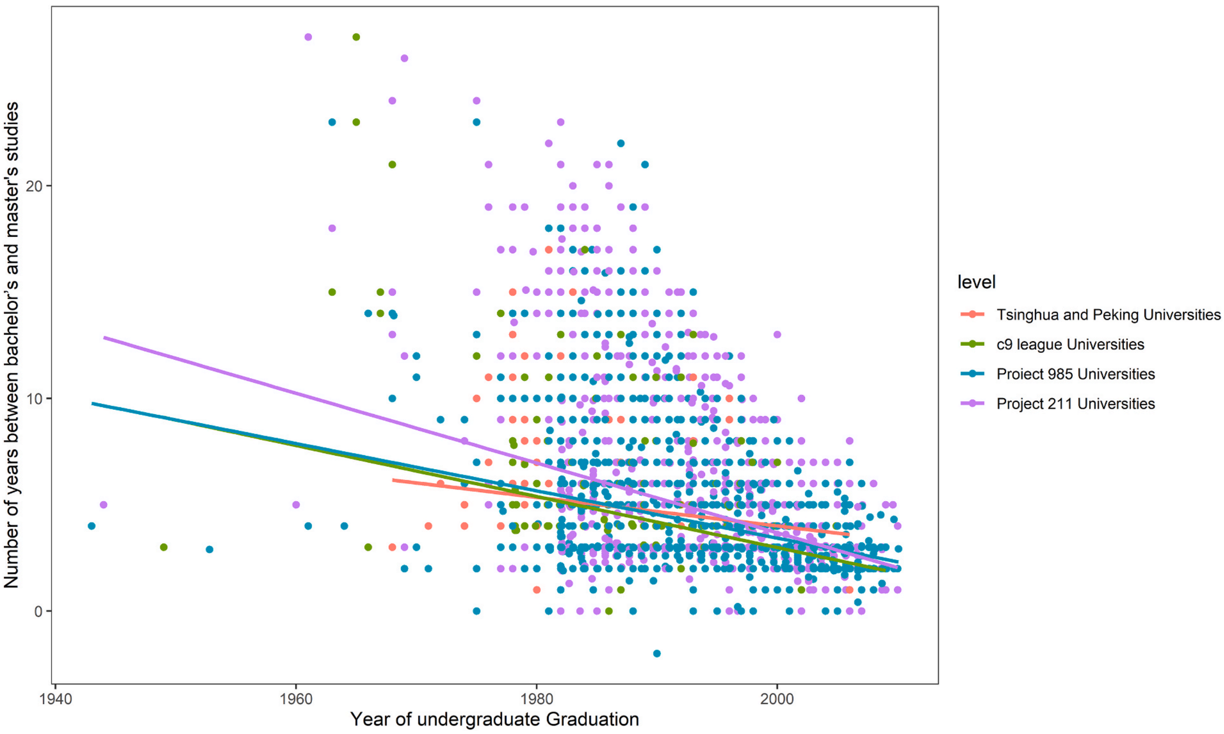

Fig. 1. Fitting scatterplot of undergraduate graduation year and the number of years between undergraduate and master’s degree.

3. Results

3.1. The academic interval between bachelor's and master's degrees and master's and doctoral degrees is getting shorter

An analysis of the data reveals that the interval between bachelor's and master's degrees and between master's and doctoral degrees is relatively short for engineering professors in all research universities in China (see Figs. 1 and 2). Moreover, the interval has gradually decreased in recent years, and the interval is shorter for professors in "Project 985″ universities compared to those in "Project 211″ universities. The data also indicates that the interval between bachelor's and master's degrees and between master's and doctoral degrees varies significantly among engineering professors who graduated at different times, with a shorter interval observed among those who graduated more recently. In the 1990s, the average interval was 1.46 years and 3.12 years for undergraduate and master's degree graduates, respectively. However, in the post-2010s, the average interval reduced significantly to only 0.20 years and 0.06 years for undergraduate and master's degree graduates, respectively (see Table 1).

In contrast, the interval between a bachelor's and a Ph.D. degree is much longer for engineering graduates from US universities. According to the National Survey of College Graduates (NSCG), which analyzed US citizens earning STEM Ph.D.'s in the US between 2000 and 2010, the period between a bachelor's and a doctorate degree exceeded ten years in 26 % of cases, fifteen years in 11 % of cases, and twenty years in 7 % of cases. Returning to the research findings of this paper, the scatterplot of the length of academic intervals between graduation and academic intervals for engineering professors in different periods demonstrates a significant decreasing trend. Additionally, the distribution of points representing "Project 211″ universities is higher than the other three types of "Project 985″ universities. Moreover, the fitted curve of the master's graduation year and the master's interval length almost intersects with the x-axis coordinate after 2010.

3.2. The ratio of doctoral-industry-university employment is meager

After analyzing the data, it was found that a low percentage of engineering professors in Chinese research universities have had industry employment after obtaining their PhD degree. However, there is a high level of consistency between their industries and disciplines, with some disciplinary differences. Of 13,688 engineering faculty members, only 733 had industry experience after their PhD, accounting for 5.35 % of the total sample. By comparison, in US universities, almost two-thirds of engineering faculty researchers had private-sector employment experience before completing their doctoral studies, and around one-third had industry jobs immediately after receiving their doctorate. Furthermore, having at least one year of industry experience is a strict requirement for new faculty hires at top US universities.

Breaking down the data further shows that 61.53 % of engineering professors with industry experience are closely related to their

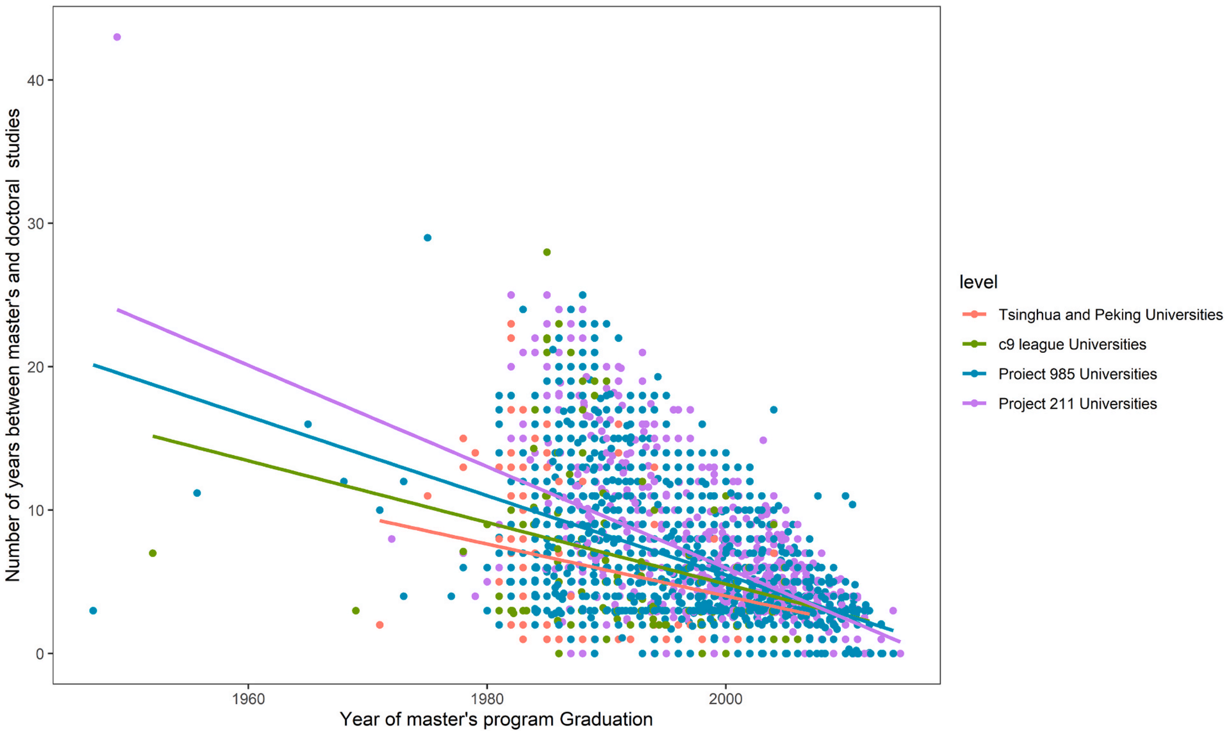

Fig. 2. Scatter chart of Master's graduation year and number of years between Master's and doctoral degree.

Table 1
The average duration of time between studies for engineering professors of different ages.

Years of Graduation	Average length of time between undergraduate and postgraduate studies (years)	Average length of time between Master and Ph.D. students (years)
1970–1979	4.03	5.87
1980–1989	2.33	5.65
1990–1999	1.46	3.12
2000–2009	0.25	0.91
2010 and after	0.20	0.06

current teaching disciplines, while 29.88 % are not related, and the nature of their work cannot determine 8.59 %. Among the various engineering disciplines, professors in mechanical, civil and construction, computer and software, and electrical engineering have high levels of consistency, exceeding 70 %, between their industry work experience and their discipline majors. In contrast, energy and power, aerospace, and electronic information have a lower level of consistency, generally below 40 %.

Overall, this data highlights the seriousness of the "three academic stages" problem in China, where about 95 % of engineering professors have no industry experience and enter universities directly after completing their PhD. This results in a lack of engineering industrial experience among university faculties. Although a few engineering professors have worked in industries, about 30 % have had work unrelated to their current specializations, reflecting a lack of disciplinary fidelity. Additionally, there are differences in the level of work and professional consistency among different engineering majors, possibly due to the practicality and job availability of

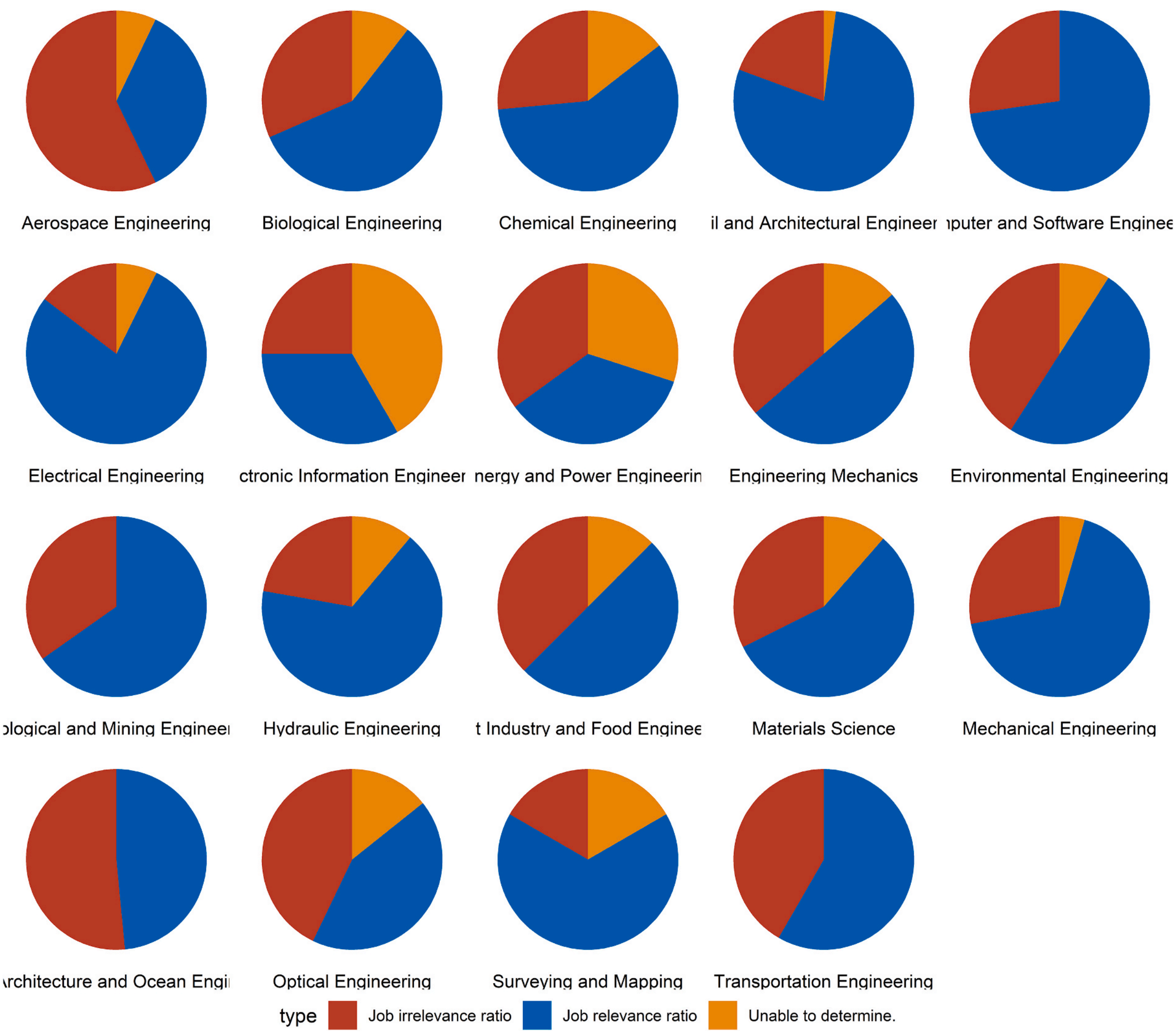

Fig. 3. Pie chart of work consistency of engineering teachers in different disciplines.

particular disciplines. For example, civil, mechanical, and aerospace engineering job vacancies are not high, leading to professors lacking professional skills in their respective fields (see Fig. 3).

3.3. Multiple factors jointly affect the industrial experience of engineering professors

The regression model indicates that gender, level of inbreeding, overseas study experience, university level, and birth age significantly affect the engineering experience of professors. The results of the logistic regression model show that professors' age, gender, level of inbreeding, overseas study experience, and university level (comparing "Tsinghua and Peking University" with "Project 211″ universities) have significant coefficients (see Table 2). The coefficients for gender and overseas study experience are 0.320 and 0.270, respectively, both passing the 0.01 significance test. This suggests that male engineering professors and professors with overseas study experience are more likely to have engineering industrial experience than their female and non-overseas counterparts. Moreover, non-inbred engineering professors are likelier to have engineering industrial experience than inbred professors (coefficient: −0.209, passing the 0.05 significance test). No statistically significant difference was found between professors of "Project 985″ universities and C9 colleges and universities, both being compared to "Project 211″ universities. However, the regression coefficient for the comparison between Tsinghua-Peking and "Project 211″ universities is −0.603, passing the 0.05 significance test. This indicates that engineering professors teaching at Tsinghua University and Peking University are less likely to have engineering experience than those in "Project 211″ universities. The factor regression coefficient for the professor's age is −0.025, passing the 0.001 significance test. The e^β value is 0.976, suggesting that as the age of engineering professors in China's universities increases by one year, the probability ratio of having industrial experience to no experience will decrease to 0.976 times the former. This reflects that younger engineering professors in China's universities are likelier to lack engineering experience. Finally, the Homser-Lemeshow test shows that the model fitting degree is suitable, as the p-value obtained (0.641) is greater than 0.05, thus rejecting the hypothesis that there is no difference between the observed value and the fitting value.

4. Discussion

The analysis of academic intervals between bachelor's and master's degrees and master's and doctoral degrees among engineering professors in Chinese research universities reveals a notable trend towards shorter intervals. This decreasing trend is particularly pronounced in recent years, with a significantly shorter academic interval observed for those graduating post-2010. Interestingly, "Project 985″ universities exhibit a shorter academic interval compared to "Project 211″ universities, reflecting nuanced variations in educational trajectories. In stark contrast, the academic interval between a bachelor's and a Ph.D. degree remains considerably longer for engineering graduates from US universities. This divergence underscores a distinctive characteristic of the Chinese academic landscape, where the academic progression is more streamlined, potentially contributing to a faster integration of individuals into the academic profession [51].

A comparative analysis between Tsinghua University and MIT demonstrates that American engineering professors exhibit more extensive engineering practice at each age in contrast to their Chinese counterparts [41]. On the other hand, the duration between obtaining a bachelor's and a Ph.D. degree is significantly longer for engineering graduates from US universities. As per the National Survey of College Graduates (NSCG), which scrutinized US citizens earning STEM Ph.D.'s in the US from 2000 to 2010, over 26 % of individuals experienced a period surpassing ten years between their bachelor's and doctorate degrees. Additionally, 11 % exceeded fifteen years, and 7 % extended to a twenty-year timeframe [52].

The data on doctoral-industry-university employment patterns among Chinese engineering professors reveals a significant discrepancy compared to their counterparts in the United States. A mere 5.35 % of the sampled professors in China have industry experience after obtaining their Ph.D., indicating a critical gap in industrial exposure within academia [53]. This stands in stark contrast to US universities, where almost two-thirds of engineering faculty researchers have pre-doctoral private-sector employment experience [54]. The lack of industry experience among Chinese engineering faculty, particularly in disciplines like energy and power, aerospace, and electronic information, reflects a broader challenge in aligning academic expertise with real-world industrial demands. The findings emphasize the urgency of addressing the "three academic stages" problem in China, where a vast majority of engineering professors lack industry experience, hindering the development of practical skills [55].

In contrast, within US universities, nearly two-thirds of engineering faculty researchers had prior private-sector employment before concluding their doctoral studies, with approximately one-third securing industry positions immediately after attaining their doctorate

Table 2
Logistic regression model results.

Variables	β	Standard Deviation, SD	e^{β}
Gender	0.320**	0.101	1.377
Inbreeding	−0.209*	0.084	0.811
Overseas education	0.270**	0.088	1.310
Age	−0.025***	0.005	0.976
College (b)	0.013	0.084	1.013
College (c)	0.140	0.118	1.150
College (d)	−0.603**	0.233	0.547

[56]. Moreover, the stringent norm at leading US universities mandates that new faculty hires possess a minimum of one year of industry experience [57].

The regression model provides valuable insights into the multifaceted factors influencing the industrial experience of engineering professors in Chinese research universities. Gender, level of inbreeding, overseas study experience, university level, and birth age collectively shape the likelihood of professors having engineering industrial experience [58]. Notably, male professors and those with overseas study experience are more likely to possess such experience, emphasizing potential gender and internationalization disparities [59]. The negative coefficient for inbreeding suggests that non-inbred professors are more inclined to have industrial experience, highlighting the influence of academic lineage [60]. The age factor further adds nuance, indicating that younger professors are more likely to lack engineering experience, potentially attributed to the evolving academic landscape and the demand for practical expertise [61]. The fitting degree of the regression model attests to its suitability, enhancing confidence in the reliability of these findings [62].

These findings align with the work of Zhou and Volkwein [63] and Cai [64], who investigated the trajectories of academic careers and industry engagement in the wake of China's higher education reforms, emphasizing the prioritization of academic output over practical application. Similarly, Shen et al. [65] highlighted differences in academic progression and industry integration between China and the U.S., pointing to systemic and cultural factors. Our analysis, by comparing our results with these prior studies, offers fresh perspectives on the complex relationship between academic timelines and industry experience, presenting a landscape shaped by historical, institutional, and policy-driven influences [66].

Furthermore, our study responds to the need for an in-depth exploration of how gender, academic inbreeding, overseas study experiences, and age affect the industrial experience of engineering professors. The regression model we utilized sheds light on these factors, corroborating and expanding upon the findings of researchers like Jiang and Esherick [67], who explored the impact of international education on academic career paths in China. Our results suggest that mitigating gender imbalances and the negative perceptions associated with academic inbreeding could lead to a more diversified and industry-connected faculty [68].

In sum, our analysis provides a critical reflection on our observations within the wider discussions on engineering education and faculty evolution in China and abroad. This study highlights the complex challenges and potential pathways forward at the academia-industry nexus, emphasizing the necessity for concerted efforts to improve the practical competencies of engineering faculty and to advocate for a more harmonized approach to academic and industry engagements. Future studies should further investigate how these dynamics affect the innovation potential and international competitiveness of China's engineering education sector [69].

5. Conclusions

In conclusion, this study provides a comprehensive analysis of the academic intervals between degrees and the industrial experience of engineering professors in Chinese research universities, uncovering significant trends and disparities. We observed a notable trend towards shorter academic intervals between degrees, particularly pronounced among professors graduating post-2010, with "Project 985″ universities exhibiting a more accelerated academic progression compared to "Project 211″ institutions. This trend reflects a distinctive characteristic of the Chinese academic system, which contrasts sharply with the longer academic intervals prevalent among engineering graduates in U.S. universities. Additionally, a significant gap in industrial experience is evident among Chinese engineering faculty, with only a small fraction having industry experience post-Ph.D. This discrepancy is particularly stark when compared to U.S. universities, where a substantial portion of engineering faculty has prior private-sector employment experience.

The study's findings highlight the multifaceted factors influencing the industrial experience of engineering professors in China. Factors such as gender, academic inbreeding, overseas study experience, university level, and birth age play a significant role in shaping the likelihood of professors having engineering industrial experience. The lack of practical experience among Chinese engineering faculty is a pressing concern, as it may impact the quality of engineering education and the development of practical skills. The observed trends and disparities underscore the dynamic nature of academic and industrial intersections within the Chinese engineering education landscape, raising important questions about the alignment of academic expertise with real-world industrial demands. This study provides valuable insights into the state of engineering education in China and highlights the need for a balanced approach to academic progression and industry engagement in order to foster well-rounded engineering faculty with practical experience.

In addressing the critique surrounding the lack of industrial experience among engineering professors in Chinese research universities, this study employs advanced data analysis methods to shed light on the professional trajectories and influencing factors of these academics. Despite the methodological strengths and the significant findings regarding the low incidence of post-Ph.D. industry employment among professors, the research recognizes several limitations that warrant consideration.

Firstly, while the study effectively identifies the variables impacting professors' industrial experience—such as gender, academic inbreeding, overseas study experience, university level, and birth age—its reliance on big data methods primarily reveals correlations without fully elucidating the causative mechanisms behind these relationships. For instance, the reason why male professors or those with international experience might have more industry involvement remains speculative within the scope of this analysis. Future research could enrich our understanding by qualitatively examining these dynamics to capture the nuanced reasons behind the observed trends.

Additionally, the methodology assumes that the presence or absence of industrial experience can be inferred from academic and professional milestones documented in publicly available CVs. This approach, while innovative, may not capture the entirety of professors' industrial engagements, potentially overlooking experiences not formally recorded or occurring concurrently with academic endeavors. Enhancing the methodological framework to include interviews or surveys could provide a more comprehensive view of professors' industry experiences.

Lastly, while this study lays a foundation for policy recommendations and future research, acknowledging these limitations opens avenues for more nuanced inquiries. Future studies could explore the impacts of specific policies on bridging the academia-industry gap, investigate the roles of mentorship and networking in acquiring industry experience, and consider the broader socio-economic factors influencing the professional development of engineering faculty.

In conclusion, while this research contributes valuable insights into the industrial experience of engineering professors in China and suggests policy interventions, it also highlights the need for continued exploration into the complex interplay of factors affecting this issue. Addressing these limitations through future research can deepen our understanding and inform more effective strategies for integrating industrial experience into engineering academia.

Data availability

All data generated or analyzed during this study are included in this published article.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Jin Liu: Supervision, Investigation. **Ilaha Balakishiyeva:** Investigation. **Kaizhe Chen:** Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Liu Jin (1985-), male, native of Donghai, Jiangsu, associate researcher at the School of Humanities and Social Sciences, Beijing Institute of Technology, researcher at the Institute of International Dispute Prevention and Resolution, Beijing Institute of Technology. Mainly engaged in higher engineering education, education big data and artificial intelligence research.

Ilaha Balakishiyeva (1996-), from Azerbaijan, female PhD student in the School of Humanities and Social Sciences, Beijing Institute of Technology.

Chen Kaizhe (1994 -), from Hangzhou, Zhejiang, male postdoctorate researcher in the School of Humanities and Social Sciences, Beijing Institute of Technology, Beijing, 100081.