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IF WE BUILD IT, WE WILL COME: INSTITUTION DEVELOPMENT IN ACADEMIA AND THE EVOLUTION OF CAREER CHOICES BY TOP TALENT DURING JAPAN'S INDUSTRIALIZATION

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ABSTRACT

Modern economies rely on academia as a critical complement to industry in generating new knowledge, and training future scientific and engineering talent that fuels endogenous growth. Academia's ability to perform this role, however, depends on recruiting and retaining talented faculty who often have lucrative alternative options in industry. Complementing existing literature focusing on factors in mature scientific labor markets, we study how this was addressed endogenously during Japan's industrialization as academic and industrial institutions were still being formed. Combining historical analysis with a dynamic occupational choice model, we utilize unique data on the census of university-educated engineers from the first forty cohorts following the establishment of higher technical education in Japan. The historical analysis shows that incumbent faculty reshaped academic governance, redefined professional purpose towards research, and created research institutes as new organizational forms. Using causal evidence from the Institute of Aeronautics and structural estimation of career choices, we find that these institutional changes increased the non-pecuniary attractiveness of academic careers, allowing universities to keep attracting a disproportionate share of top talent despite a widening pay gap with industry. The findings demonstrate how non-pecuniary incentives emerge through institution building and how this reshapes organizational responses across academia, industry and state.

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I. INTRODUCTION

The role of human capital in modern development is well established (Becker, Hornung, and Woessmann, 2011; Goldin, 2001), and higher science and engineering (S&E) education institutions play a central role in the endogenous growth process not only by training industrial scientists and engineers, but also by generating new knowledge that contributes to technological advances, industry evolution and economic progress (Nelson and Rosenberg, 1993; Romer, 1990). Prior work has shown that academic institutions are shaped by policy interventions and public investments (Becker et al., 2011; Hvide and Jones, 2018). Yet, the contribution of academia to economic development ultimately depends on whether it can recruit and retain highly talented faculty—individuals who often have lucrative alternative options in industry.

Securing such talent is increasingly challenging. Anecdotal accounts, such as Uber's poaching of the forty top researchers from the Carnegie Mellon University robotics department (Ramsey and MacMillan, 2015) echo systematic evidence that lifetime earnings are higher in industry, and that increasing wage differentials between industry and academia over time have resulted in reduction of academia's shares of S&E doctorate recipients (Agarwal & Ohyama, 2013; Boudou, 2024; Ehrenberg, 1991; Roach & Sauermann, 2017; 2024). Research on mature scientific labor markets in advanced countries—primarily in the U.S.—has emphasized that academia attracts talent by catering to non-pecuniary preferences, including autonomy in pursuing research and professional status in scientific communities (Merton, 1973; Stern, 2004; Stephan, 1996). However, these studies typically take both such preferences and institutional features that support them as given. They offer limited insight into how academic institutions came to embody these characteristics in the first place, or how such features evolved in response to changing economic conditions.

This paper adopts a dynamic perspective on the evolution of academic institutions and scientific labor markets. We study Japan during the late 19th and early 20th centuries—a period in which both industrial and academic systems were built largely from scratch. Because the non-pecuniary features associated with academic careers had not yet crystallized, this context allows us to examine the strategic factors shaping how they emerged, how they were sustained, and whose actions mattered in the process. In doing so, we also illuminate the role played by academics themselves in shaping the institutions within which they worked.

We assemble a novel dataset covering the critical period during which Japan's industrial and academic sectors coevolved to become the primary employers of scientific talent. The data include historical records on the evolving structures and practices of the Imperial University system—which constituted nearly the entirety of Japanese academia during this period—as well as career histories for the full census of the first 40 graduating cohorts from the Tokyo Imperial University College of Engineering.

Two patterns in the data motivate our analysis. First, although pecuniary compensation in academia was initially comparable to that in industry, the earnings gap widened substantially as Japan's industrialization gained momentum. Second, rather than creating an exodus of top talent from academia, the Imperial University system attracted and retained a high—and over time increasing—share of top-ranked graduates as faculty. Existing explanations based on mature scientific labor markets offer limited insights that reconcile these patterns.

To explain these patterns, we first conduct a historical analysis of institution-building with the Imperial University system. A key question, particularly relevant from the strategy perspective for various stakeholders, is what forces shaped Japan's institutions: what were the roles of deliberate ex-ante planning by the government, the stance of firms within industry, and the strategic efforts of members of the academic community themselves? We document how faculty, while adhering to strong cultural taboos against negotiating higher pecuniary compensation (Nitobe, 1908), undertook sustained efforts to reshape non-pecuniary aspects of academic work. These efforts included expanding academic freedom in governance, redefining professional purpose around research, and creating research institutes as new organizational structures that enabled long-horizon, industry-relevant basic research. While the government retained formal authority over universities, we show that many pivotal changes originated within academia itself, with public authorities often sanctioning or codifying reforms after the fact. Over time, these faculty-led initiatives altered the nature of academic careers and the relative attractiveness of academia for top scientific talent.

We then turn to the consequences of these institutional changes for individual career choices. Using earnings and occupational histories of top graduates, we estimate a dynamic structural model of occupational choice between academia, industry and the government. This approach allows us to account explicitly for selection: lower observed earnings in academia do not, by themselves, imply weaker incentives if counterfactual earnings in alternative sectors would have been even lower. The structural estimates show that non-pecuniary payoffs associated with academic employment increased across cohorts, offsetting the growing wage gap with industry. Counterfactual simulations suggest that, absent these institutional changes, the Imperial Universities would have lost more than 40 percent of their top faculty by the 1930s.

The analysis also reveals that these developments had implications beyond academia. As institutional innovations such as academic research institutes expanded the scope and orientation of academic research, they influenced how private firms and public agencies organized their own research activities and accessed scientific expertise. In the short run, the academic research helped spawn new industry-related technologies; in the long term, the institutional innovation created a stable structure and incentive mechanisms to train a future pipeline of industrial and academic talent within domestic universities, while retaining a disproportionate share of top talent within academia. Rather than a zero-sum competition between academia and industry, the historical record points to a pattern of differentiation and complementarity that supported both scientific advancement and industrial development.

In summary, the historical setting examined in this paper makes it possible to observe how institutions that are now taken for granted emerged through the interaction of multiple organizational actors. Government authorities shaped the formal parameters of higher education through funding rules, salary schedules, and legal governance arrangements. Private firms created increasingly attractive outside options for scientific talent as industrialization accelerated and technological opportunities expanded. Within this evolving environment, incumbent faculty played a central and proactive role. Confronted with widening earnings gaps and limited scope for pecuniary adjustment, faculty undertook sustained efforts to reshape academic governance, redefine professional purpose, and create new organizational structures that supported research autonomy and long-horizon inquiry. Importantly, these faculty-led initiatives did not unfold in isolation. As academic institutions evolved, they altered the opportunity sets faced by other organizations. Public authorities increasingly sanctioned and codified changes that originated within universities, while private firms adapted how they organized research, sourced foundational technologies, and accessed scientific talent. Tracing this sequence reveals how institution building in academia—driven primarily by faculty agency—triggered a broader process of organizational adaptation, reshaping patterns of talent allocation and the development of industrial research capabilities over time.

By tracing the evolution of academic institutions and career choices during Japan's industrialization, this study offers insights relevant to both developed and developing economies in modern day. For developed countries with established systems, it sheds light on some big-picture questions salient today. These include the impact on career choices of scientists and engineers in modern-day high-tech sectors as firms seek to lure talent away from academia. It also illuminates potential long-term impact of government policies that alter inflows of students into academia, financial support for academic mission, and autonomy of the academic sector (cf. Merton, 1938). For developing economies facing challenges of 21st century's global positioning, it highlights the importance of institutional design in allocating scarce talent in industry vs. academia to light of short- and long-term tradeoffs in individual and social costs and benefits. Of particular note is the strategic creation of research institutes that focus on basic research for industrial use as a structural alleviation of these tradeoffs, with long-term consequences for innovation and growth.

The rest of the paper proceeds as follows. Section II describes the historical context. Section III introduces the data and research design. Section IV documents patterns of faculty selection and retention. Section V presents the historical analysis of institution-building in academia, with particular attention to the emergence of research institutes. Section VI develops and estimates the structural model of occupational choice, and Section VII presents counterfactual simulations. Section VIII concludes.

II. RESEARCH CONTEXT: HIGHER TECHNICAL EDUCATION DURING JAPAN'S INDUSTRIALIZATION

The Meiji Restoration of 1868 marked the start of Japan's rapid catch-up development. At the time, Japan completely lacked engineering and other forms of higher science and technical education; this had to be built from scratch through initial reliance on invited foreign teachers (Dyer, 1904; Nakayama 1978). The Imperial College of Engineering (*Kobu Daigakko*) opened in 1877, with the first 22 recipients of the Bachelor of Engineering (*Kogakushi*) degree graduating in 1879.

The transition from invited foreign teachers to domestically grown talent began gradually, but by the time of the merger of Imperial College of Engineering with the University of Tokyo for the first Imperial University[1]

[1] The first Imperial University was renamed "Tokyo Imperial University" after the second Imperial University was established in Kyoto (see below). In our data described in the next section, we use the sample of engineering graduates from Tokyo Imperial University, but when examining their occupational choices, we define academia to include faculty positions in all Imperial Universities.

in 1886, almost half of the faculty were its own graduates. The fraction of own graduates among Tokyo Imperial University College of Engineering faculty continued to increase and exceeded 90% from the 1910s (Figure 1).

[Figure 1 around here]

The (Tokyo) Imperial University College of Engineering was the only place to obtain university-level engineering education in Japan for 20 years. Subsequently, Kyoto Imperial University was established in 1897 (with the first cohort graduating in 1901) and two more Imperial Universities—Kyushu and Tohoku Imperial Universities were established in the 1910s to provide higher technical education. Nonetheless, Tokyo Imperial University remained the largest and most important.

Faculty in the Imperial Universities were comprised of two types—full and assistant professors ("core faculty") and other faculty members, such as lecturers. While lecturer positions could be converted into assistant professor positions, most (more than two thirds) were part-time positions where individuals had main jobs elsewhere, for e.g., in the private or public (military) sector. This resulted in differences in job tenures across the two position types: for instance, in Tokyo Imperial University College of Engineering the tenure for core faculty was 13.3 years on average across our time frame, while it was 5.4 years for lecturers. Given these differences, we define "academic career choice" as having the primary job as a member of core faculty in one of the Imperial Universities.

The development of engineering education in Imperial Universities proceeded in parallel with the process of industrialization, as Japan closed the gap with advanced nations (Figure A1 in the Appendix). As in other industrializing economies, mechanized cotton spinning industry was the first one to emerge, and university-educated engineers played a critical role in its development (Agarwal, Braguinsky, and Ohyama, 2020; Braguinsky, Ohyama, Okazaki, and Syverson, 2021). After the turn of the 20th century and especially during World War I, the country started diversifying into heavy and chemical industries. Thus, the competition for top engineering talent from industry (the private sector) as well as from the government (including the military) was very high, intensifying over time, and presenting serious challenges to recruiting and retaining talent in academia.

III. Data and Research Design

III.1 Brief Data Description

We leverage multiple sources to build a unique database consisting of longitudinal quantitative and qualitative data. First, we draw upon the annual Imperial Universities' Calendars (such as *Tokyo Teikoku Daigaku Ichiran,* 1886-1939), available in open access from the National Diet Library Digital Collections (https://dl.ndl.go.jp/en/). We digitized information on all graduates from Tokyo Imperial University College of Engineering and its predecessor (Imperial College of Engineering) from the first cohort in 1879 and until 1918. These data were then hand-matched with the annually released lists of the Alumni Association of Imperial Universities (*Gakushikai Kaiin Shimeiroku,* 1890-1940) which start from 1890 and contain address and workplace information. We were able to match more than 90 percent of graduates to the alumni lists; this enabled annual updates for workplaces and addresses. Please see Appendix B for a detailed description.

We matched the graduates in the above dataset to manually compiled data covering all the faculty in Imperial Universities' engineering colleges and departments from the annual Imperial Universities' Calendars in the previous paragraph, which also contain information on faculty members in each year (names, job titles such as professor, assistant professor, lecturer, etc., and specialization). Importantly, our data extract on Tokyo Imperial University graduates from the University Calendars includes additional rich information about students' academic achievement. Specifically, according to Tokyo Imperial University rules placed from its inception and through 1918, its students in each year and graduates at the time of graduation were listed in the order of how they ranked based on academic achievement relative to peers (*Sekiji*, in Japanese—see, e.g., *Tokyo Teikoku Daigaku Ichiran*, 1907, p. 198) .[2]

Based on the above two databases, and because graduation rankings—a key variable in our analyses for examining selection into academia, industry and government are available up to 1918—our sample includes 40 total cohorts of graduates from the Imperial University College of Engineering. Figure A2 in the appendix shows the evolution in the number of graduates between 1879-1918. Beginning with small cohorts (20-30 engineers per year), the graduating class increased steadily in size from the mid-1890s to almost 200 graduates per year in the 1910s. Most of the growth in graduating cohort size stemmed from increased enrollment in

[2] The listing of students and graduates in the order of *Sekiji* was discontinued and replaced by alphabetical ordering in 1919 (*Tokyo Daigaku Hyakunenshi*, 1977, Vol. 2, p. 214).

already established divisions (notably, mechanical engineering, electric engineering, applied chemistry, and naval architecture), though sub-divisions that enabled more specialized education also contributed to growth.

To obtain earnings data for the quantitative occupational job choice model, we relied on Japan's annual *Who is Who* (*Nihon Shinshiroku*), which reported income taxes paid by those listed in it from 1902 on and used information on income tax schedules reported in the annual reports of Japan's Tax Bureau (*Shuzeikyoku Tokei Nemposho*, 1896-1933) to calculate incomes. Data and time limitations preclude our ability to collect income tax data for all several thousand College of Engineering graduates in our overall data. As a result, our data only include information on top-ranked graduates, whom we painstakingly and manually matched using information in each source on names, addresses, and workplaces. We were able to match 258 top-ranked graduates out of the total of 301 (86 percent) to *Who is Who* in at least one year, giving us 3,293 hand-coded income tax (and income) observations in years 1902-1933. We use this sample of 258 top-ranked Imperial University College of Engineering graduates in the structural estimation in Section VI. See Appendix B for more details.

III.2 Research Design and Methodology

Data-Driven Research Question

Our research design consists of four parts. In Section IV, we begin by presenting data that motivates the study's research question by focusing on trends in top scientific talent selection and retention in academia (core faculty of Imperial Universities). To do so, we utilize graduation rankings data matched with faculty lists to document share of top-ranked graduates among Imperial University faculty and provide some illustrative cases. Next, we use information on all graduates from the annually updated panel data described above to present the dynamics of employment shares in three major employment sectors: academia, the private sector (industry) and the public sector (primarily military and government, and also lower-level educational institutions). Here, we depict trends in employment shares in each sector for all graduates and for the subsample of top graduates.

Our study is motivated by a salient observation that emerges from these evolutionary trends: even as more graduates (including top-ranked ones) chose industry over time, academia was nonetheless able to attract and retain a disproportionately high and increasing share of top-ranked graduates. Why and how did it do so, given that these graduates could command significantly higher premiums in industry? We utilize mixed methods to delve into rich panels of data to shed light on the evolutionary process, and the resultant effects on occupational choice. We provide a brief roadmap below of our use of historical methods in Section V, structural model estimation of occupational choice in Section VI and counterfactual simulation in Section VII.

Historical Approach: The Evolution of Pecuniary & Non-Pecuniary Attractiveness of Academic Jobs

Given our focus on evolutionary processes, we eschew the traditional approach in studies of occupational choices that examine the role of incentives under "equilibrium conditions" of mature scientific labor markets (Ehrenberg, 1991; Stern, 2004; Roach and Sauermann, 2010; Agarwal and Ohyama, 2013; Sauermann and Roach, 2017). Instead, we adopt an explicitly historical approach and utilize quantitative and qualitative data on pecuniary and non-pecuniary incentives to analyze the evolution of Imperial University faculty jobs along these dimensions. Specifically, this part of our study seeks to answer the following research questions: How did pecuniary compensation in academia vs. industry change over time? How did institutional changes in academic structures influence underlying non-pecuniary preferences of faculty and their strategies to address them?

For pecuniary incentives, we utilize quantitative data on university salary scales and individual-level data on earnings of top graduates to gauge academic faculty compensation relative to peers in the private and public sectors. For non-pecuniary incentives, we elucidate trends in critical aspects of academic positions, especially creation of research institutes as novel organizational structures. The creation of the Institute of Aeronautics in particular presents us with an opportunity to implement causal identification. We also show how these changes were affected by strategic shaping of the "rules of the game" in academia by faculty itself and how industry came to embrace the win-win nature of strategic collaboration with top talent in academia.

Structural Model Estimation: The Evolution of Occupational Choices of Top Scientific Talent

This part of our study seeks to answer the following research questions: How did changes in pecuniary and non-pecuniary incentives offered by academia affect scientific talent allocation across industrial and academic sectors? Relatedly, what was the role of institution building efforts and increase in non-pecuniary incentives in academia in the process, as evident from counterfactual simulations of their absence?

To answer these questions, we utilize the insights from the historical analyses above to inform the occupational choice model (Roy, 1951) in Section VI. We use data on earnings and occupational choices of top graduates to conduct estimations employing commonly used dynamic structural model frameworks (Keane and Wolpin 1997; Traiberman, 2019). Such estimation allows us to embrace the endogeneity in occupational choice and quantify the role of non-pecuniary preferences in talent allocation that the historical analyses in the previous sections reveal to be critical but are unobservable in the quantitative data. As explained in more detail in Section VI, the model structure incorporates the evolution of structural conditions facing cohorts (early vs. later graduates) to explicitly address the role of the changes in non-pecuniary returns in Section V, as they governed occupational choice and produced the trends in talent allocation noted in Section IV.

In the final Section VII, we illustrate how the structural estimation fits the actual time trends shown in Section IV: in contrast to a reduced form estimation, these fitted trends incorporate how institution building affected the attractiveness of faculty jobs documented in Section V. In particular, we examine counterfactual scenarios—*how would talent have been allocated if there was no institution building that catered to non-pecuniary preferences in academia?*—by "shutting down" key parameters in the structural model associated with institution building efforts and role of non-pecuniary motivations to illustrate how these impacted the allocation of talent.

IV. TRENDS IN TALENT SELECTION IN ACADEMIA

A critical requisite for building a higher education system from scratch is the selection of talented individuals for filling faculty positions. Studies by Japanese historians describe faculty recruiting by the Imperial Universities as focused on the very top students: "*candidates to become university professors were those who graduated with honors and a special nurturing path was open to them*" (Iwata, 2021, p. 24). However, these authors also noted that top graduates had multiple career options in the private and public sector and their path to the country's elite professionals was by no means limited to the academic profession alone (*ibid.*, p. 141). Given this context, how successful were the Imperial Universities' efforts to recruit and retain top talent?

Figure 2 presents the empirical cumulative distributions of university graduation rankings among the first (Tokyo) Imperial University engineering faculty, averaged across all observation years in our data. Top-ranked graduates on average accounted for half of all core engineering faculty, with 80 percent of core faculty positions occupied by those who graduated in the top three ranks of their cohort. Though Figure 2 seems to indicate that success in recruiting and retaining top talent as its faculty, Figure 3 reveals important temporal differences.

[Figures 2 and 3 around here]

It turns out that in the initial years, academia struggled to recruit or/and retain top graduates and experienced high turnover rates. Take the example of Ichisuke Fujioka, a top-ranked graduate in electrical engineering (see Appendix C.1 for details). Even though the University was able to recruit him as an assistant professor in 1886, he quit shortly thereafter and later became the founder of one of the predecessor companies of today's Toshiba. As depicted in Figure 3, during the first 14 years after inauguration (1886-1899), the share of top graduates among Imperial University engineering faculty (both core and all faculty) was below 50 percent. Appendix Figure A3 reveals that during this time, the annual quit rates among Imperial University College of Engineering faculty were on average 16 percent and the turnover rates (the sum of new hires and quits, divided by the total number of faculty in a given year) exceeded 40 percent.

The situation subsequently changed. The share of top-ranked graduates among core engineering faculty exceeded 50 percent for the first time in 1903 and increased to well over 60 percent in 1906-07 and again in the mid- to late 1910s (Figure 3). Turnover and quit rates, especially among core faculty, plummeted to less than 5 percent by the 1914-1920 period (Appendix Figure A3). There was a clear trend toward increased coalescence of engineering faculty around some core value propositions which, as shown below, were not built around pecuniary compensation (at least not entirely around pecuniary compensation). It is also important to note that only less than 40 percent of all core engineering faculty joined academia within five years of graduation, while the remaining 60 percent became core faculty after on average 6.7 years of prior experience in the private or public/military sector. Furthermore, as shown in Appendix E, the share of such "later joiners" (coming after prior experience in other sectors) was much higher (almost 70 percent) for those who were hired in 1908-1920 compared to 30 percent among those hired prior to 1908. Thus, the Japanese academic sector presented attractive job opportunities not just to new graduates, but also to middle-career individuals.

Digging deeper into sectoral allocation of talent, Figure 4 shows the dynamics of employment distribution of all engineering graduates (solid lines) and top-ranked graduates (dotted lines) across the three sectors during 1902-1933. Two things stand out. First, although academia represented only about seven percent of all graduates across most years, its share among top-ranked graduates was several times higher, at 25-30 percent.

The degree to which academia was able to disproportionately attract top talent to its ranks is remarkable.[3] Second, and consistent with the incipient stages of industrialization in Japan's economy, the public sector was the principal employer of all engineering graduates through the mid-late 1900s. Thereafter, the fractions employed in the private sector steadily increased from 40 percent to 60 percent among all graduates and from 30 percent to 45 percent among top-ranked graduates. Importantly, while there is a clear trend toward reallocation of university-educated engineering talent from the public to the private sector as industrialization accelerated, the fraction of (both all and top-ranked) graduates employed in academia remained essentially stable (and even increased slightly late in the sample). Thus, and in contrast to the public sector at large, academia was able to withstand the pressures and not lose shares to the private sector, especially among top talent.

[Figure 4 around here]

In summary, the trends in Figures 2-4 and accompanying Appendices reveal that a) the relative share of top talent to all graduates in academia increased over time and b) unlike the public sector's loss in share of talent to the private sector, academia's share was relatively stable. Since Imperial Universities were under government ownership, it was by no means a given that academia would not follow the same trend as the public sector considering increased industrialization. We next turn to our historical deep dive to elucidate factors at play for later cohorts of top-ranked graduates to be more drawn to academia relative to earlier cohorts.

V. INSTITUTION-BUILDING EFFORTS AND EVOLUTION OF JAPAN'S ACADEMIC SECTOR

Career choices of S&E graduates are shaped by the match of pecuniary and non-pecuniary incentives offered by different sectors to individual preferences and ability (Agarwal & Ohyama, 2013; Sauermann & Roach, 2014). Focusing primarily on the US, rich literatures in economics/management of science highlight that while pecuniary returns are higher in industry, academia attracts talent by catering to individuals' preferences for science and autonomy, supported by a social ethos that privileges status derived from creation of new knowledge (Merton, 1973; Dasgupta and David, 1994; Stephan, 1996; Stern, 2004). Such characteristics are also observed in other modern-day developed economies, including Japan (Arimoto, 2010; Nakayama, 2009).

[3] Table A2 (Panel A) in the appendix presents a similar picture by showing the shares of Imperial University College of Engineering graduates who became faculty in their alma mater at least once in their whole careers (followed until 1939). This share was also seven percent on average across all divisions and cohorts up to 1918, but among top-ranked graduates, almost a third (32%) were listed as engineering faculty member at least once during their careers (Table A2, Panel B).

The existence of such social ethos, however, cannot be taken for granted. As noted above, it was largely absent in Japanese academia at the onset.[4] How such a social ethos emerges, how it evolves, and how it can be strategically enhanced and sustained amidst changing socio-economic environment remain largely unexplored questions— despite their central importance for understanding the allocation of talent across academia, industry, and the state, and their implications for both modern-day academia and business strategy.

The historical evidence presented below shows that, government efforts notwithstanding, pecuniary incentives in Japan's academia could not keep pace with those in industry. Instead, academia's growing ability to attract and retain top talent hinged on the gradual evolution of institutional characteristics that increased the non-pecuniary attractiveness of academic careers. These changes were not automatic. Rather, they emerged through a sequence of deliberate, faculty-led institution-building efforts that created new organizational forms—most notably research institutes—that expanded autonomy, research scope, and professional rewards, while simultaneously reshaping and co-evolving with strategic options available to firms within industry.

V.1 Pecuniary Compensation in Academia Relative to Other Sectors

Ethical norms deeply rooted in *Bushido* ("The way of the samurai") created strong cultural taboos against members of the academic elite negotiating their own earnings.[5] As a result, adjustments to pecuniary compensation in academia were determined almost entirely through government action rather than faculty initiative. Beginning with the 1893 Imperial Edict, the government instituted several measures aimed at increasing the pecuniary attractiveness of academic positions, most notably by introducing Imperial University-specific salary schedules. As shown in Appendix Table A1, these schedules exhibited high dispersion, with a pronounced trend toward greater pay differentiation within the same academic ranks over time. In addition, a shift towards improving compensation earlier in academic careers is evident in changes to assistant professors' salaries relative to those of full professors: while assistant professor salaries were set at half of full professor

[4] *"[D]uring the first six-seven years of its existence, the teaching job at the Imperial University had not been as highly socially prestigious as it became later … not a small number of individuals would move on to other government jobs or jobs in the private sector. … Factors related to low compensation especially for new, young academics and barriers to promotion were major problems."* (Terasaki, 2000, p.45)

[5] *"The present system of paying for every sort of service was not in vogue among the adherents of Bushido. It believed in a service which can be rendered only without money and without price. Spiritual service, be it of a priest or teacher, was not to be repaid in gold or silver, not because it was valueless but because it was invaluable. … Usage sanctioned that pupils brought to their teachers money or goods … but these were not payments but offerings, which indeed were welcome to the recipients … [as] an embodiment of what was considered as an end of all learning … a living example of … self-control which was universally required of samurai.*" (Nitobe, 1908, p. 90-92.)

salaries until 1918, this ratio increased to two-thirds of full professor salaries after 1919. Together with mandatory retirement age introduced a few years later, these changes reflected an explicit policy effort to make academic careers more attractive to top young talent.

The 1893 Imperial Edict also introduced the course chair system ("*Kozasei*"), which divided salaries into a basic salary (*honpo*) determined by the formal scales in Appendix Table A1, and a service allowance (*shokumuho*). Progression in the basic salary scale remained tied to the length of service, but the service allowance was decoupled from tenure and instead depended on the number and difficulty of courses taught. Subsequent Imperial edicts further supplemented this system by introducing merit-based increases, which partially offset the erosion of real salaries due to inflation (Appendix Table A1, Panel B).

To assess the material impact of these reforms to academic compensation relative to other sectors, Table 1 presents reduced-form estimations of earning differentials using income data from 1902-1933 for the sample of top-ranked graduates, observed up to 35 years after graduation). Specifically, we regress logged incomes on sector indicators, quadratic terms in years since graduation, and time trend interactions with sector indicators.

[Table 1 here]

The estimation results show that, consistent with the findings from U.S.-based studies, earning profiles in academia were flatter than in the private sector. Moreover, the interaction between private-sector employment and the time trend is positive and statistically significant, indicating that earnings trajectories in the private sector shifted upward over time. In contrast, comparable upward shifts are absent in academia. Thus, while the Imperial University system's use of service allowances, merit increases, and greater pay differentiation succeeded in temporarily narrowing pecuniary gaps—particularly early in academic careers—these measures failed to keep pace with rapidly rising earnings available in the private sector. Importantly, our data capture all taxed earnings rather than basic salaries alone. These findings are consistent with historical accounts emphasizing the growing limitations of pecuniary incentives, driven by both the expansion of private-sector opportunities and rigidities inherent in Imperial Universities as public institutions (Morikawa, 1975; Iwata, 2021).

V.2 The Evolution of Non-pecuniary Incentives: Academic Freedom and Autonomy

Turning to non-pecuniary attractiveness of academic careers, at time of founding, the Imperial College of Engineering (later the College of Engineering in the first Imperial University) was not strategically oriented towards providing academic freedom or opportunities for independent research. Instead, it was administered as a centralized bureaucratic organization whose primary mission was to educate future government officials and advance state priorities. The limited attention to the creation of new knowledge is evident in the 1889 address to Imperial University faculty given by Arinori Mori, Japan's first Minister of Education, delivered three years after the Imperial University's inauguration:

> *"…Imperial University should absolutely prioritize the Country when deciding whether to conduct its activity for the sake of research or in the interest of the Country … [if] one who works in academia and teaching … has little aspiration for the Country, such a person does not belong in academia."* (Cited in Tokyo Daigaku Hyakunenshi, 1977, Vol. 1, p. 797, authors' translation from Japanese.)

This narrow conception of faculty's roles was reinforced by formal governance rules that restricted faculty responsibilities to "*administering college-related matters within the realm determined by the orders of the President of the University,*" who in turn operated under direct instructions from the Minister of Education (*Tokyo Daigaku Hyakunenshi*, 1977, *Vol.* 1, p. 799). Academic autonomy, as understood in later periods, was largely absent.

From the outset, however, top-talented individuals drawn to science and engineering—many influenced by foreign instructors and exposure to universities abroad—chafed at this constrained definition of academic work. Some responded by leaving academia altogether, as reflected in the high early-career attrition documented in Section IV. Others remained, and undertook sustained efforts to alter the non-pecuniary payoff structure of academic employment. Importantly, these efforts were not directed at pecuniary compensation—which cultural norms rendered largely non-negotiable—but at reshaping governance, autonomy, and professional status.

The earliest attempts to reform university governance structure emerged in 1887, just one year after the Imperial University's inauguration. The most ambitious proposal was drafted by a group of 27 young professors—many of whom would later become central figures in Japanese science and engineering—and called for redefining the Imperial University as an "*autonomous organization with its own legal status, separate from and independent of the government*" (*Tokyo Daigaku Hyakunenshi*, 1977, Vol. 1, p. 830). Central to the proposal was a strengthened role for department-based faculty assemblies (*Kyojukai*), envisioned not merely as advisory bodies but as active participants in academic appointments and internal governance.

Although the government did not adopt the most radical elements of these proposals, it incorporated several key components in the 1893 Imperial Edict, a turning point in the evolution of non-pecuniary incentives in academia. The edict included measures to elevate the social status of academic positions; a redefinition of the University President's role from "*acting on the orders from the Minister of Education*" to "*acting under the supervision of the Minister of Education in accordance with the provisions of the Law on Imperial University*;" the elimination of external political appointments to college-level Dean positions; and the first legal codification of faculty assemblies. Over subsequent decades, these changes were reinforced through a series of conflicts (see Appendix C.2). Most notably, two high-profile incidents in the early 20th century resulted in faculty assemblies successfully asserting decisive voice in personnel decisions. These struggles culminated in the institutionalization of faculty election of university presidents, a governance structure that remains in place in Japanese universities today.

V.3. The Emergence of Academic Purpose and Social Ethos Centered on Research

The governance reforms described above changed *how* academic institutions were governed—the shift toward greater faculty autonomy and internal governance of the university system was important as it provided increased prestige, intellectual independence, and career stability. Their most important consequence was *why* those institutions existed: the faculty used newly acquired autonomy for the gradual redefinition of academic purpose itself—from a narrow focus on teaching and state service toward the systematic production of new knowledge through research. This reorientation was neither automatic nor immediate; rather, it unfolded in response to the changing technological and industrial context confronting Japan during rapid industrialization.

As Japan transitioned from light manufacturing towards science-based heavy and chemical industries, the limitations of a university system focused primarily on teaching became increasingly apparent. Prominent scientists articulated these concerns explicitly. Hantaro Nagaoka, a leading physicist and a later founder of an important academic research institute, lamented Japan's growing "trade imbalance" in scientific knowledge relative to other countries. Similarly, Jokichi Takamine—the world-renowned chemist based in New York, discoverer of adrenaline, and co-founder of Sankyo Corporation—warned that Japan's industrial technologies "*present extremely little originality* …[and that] *it is not feasible to stick with copying others forever*" in an address to Japan's Chemical Industry Association in 1913 (Kamatani, 2006, p. 73).

Against this backdrop, academic institutions evolved through deliberate efforts—led primarily by faculty and with support of multiple stakeholders—to reorient the university mission towards research. For nearly two decades after the Imperial University's founding, faculty research activity remained limited, reflecting the institution's original teaching-centric mandate. One manifestation of this constraint was the early decline in the practice of sending promising scholars abroad for advanced training, historically a key channel for importing frontier knowledge. Data from Imperial University calendars indicate that fewer than five percent of engineering faculty were on sabbatical abroad in any given year between 1886 and 1899.

As concerns about Japan's research capacity intensified, this policy was reversed. The share of engineering faculty on overseas research more than doubled to 11 percent in 1900-1913. Young assistant professors were increasingly granted paid sabbaticals for two-three years at leading universities and research institutes in Europe and the US. Upon return, they were typically promoted to full professors and awarded doctorate degrees. These institutionalized career pathways created a credible mechanism through which research effort translated to professional advancement. As a result, faculty positions became substantially more attractive to top young talent, including individuals who had previously contemplated leaving academia (Iwata, 2021; Terasaki, 2000).

This endogenous shift toward research orientation also altered the nature of academic output. Top engineering faculty increasingly began to pursue commercially applicable, industry-related technologies, signaling a departure from the purely pedagogical conception of academic work.[6] External shocks further accelerated this transformation. The onset of World War I (WWI) disrupted imports from Europe, the primary source of embodied advanced technologies—and heightened awareness among military and industrial leaders of the strategic importance of domestic scientific capability for national security and economic resilience, particularly in chemical and heavy industries (*Tokyo Daigaku Hyakunenshi,* 1997, Vol. 7, p. 30).

In response, senior faculty played a central role in identifying institutional solutions to these emerging challenges. Their efforts catalyzed a broader alignment among academia, government, and the private sector around the need to create new organizational structures—academic research institutes—that supported sustained, autonomous, and industry-relevant research. These institutes represented a critical next step in the evolution of Japan's academic social ethos and purpose, translating abstract commitments to a research mission

[6] For example, Ariya Inokuty, core faculty member of the Imperial University Mechanical Engineering division since its inception in 1886 received 12 domestic and five global patents. He started outsourcing commercial applications of his theories on centrifugal pumps to a private company in 1909. When that company went bankrupt in 1912, Inokuty and his former student and co-inventor Issei Hatakeyama immediately co-founded a new venture to commercially produce their invention of centrifugal pumps. The new company grew to become EBARA, a global corporation with over 20,000 employees and $6 billion in revenue as of 2024 (https://www.ebara.co.jp/en/).

into concrete organizational platforms, and setting the stage for the co-evolution of academic, industrial, and government strategies examined in the sections that follow.

V.4. The Emergence and Evolution of Academic Research Institutes

The reorientation of academic purpose toward research described above created both the demand and the legitimacy for new organizational forms within academia. Traditional university departments were ill-suited to sustain large-scale, long-horizon, and capital-intensive research programs, particularly in emerging technological domains. Departmental structures were primarily organized around teaching responsibilities and disciplinary boundaries, limiting the scope of inquiry faculty could pursue even after autonomy had increased. Beginning in the mid-1910s, academic research institutes emerged as a faculty-designed organizational response to these constraints. By separating research from routine teaching obligations and by enabling independent control over research agendas, personnel, and resources, institutes expanded the feasible scope of academic inquiry beyond what departments—or firm and government laboratories—could support.

In Section V.4.1, we combine qualitative historical evidence with quantitative analysis to examine faculty-led founding of the first major university affiliated institute—the Institute of Aeronautics at Tokyo Imperial University—and use this case to provide causal evidence that research-focused institutional innovations increased non-pecuniary attractiveness of academic careers for top talent. Section V.4.2 documents subsequent proliferation of similar research institutes across Imperial universities and as stand-alone organizations. Section V.5 examines how these institutes became sites of strategic alignment across sectors, as government—and crucially—private firms increasingly supported academic research institutes to access broad, uncertain, and industry-relevant basic research, while also leveraging academic talent for consulting and recruitment.

V.4.1. The Institute of Aeronautics: A Case Study for Causal Identification and Inference

The creation of the Institute of Aeronautics provides a unique opportunity to examine the causal impact of the institutional innovation, as its effects were largely confined to two specific divisions within the College of Engineering—Mechanical Engineering and Naval Architecture—and it was the first major research institute formally established in affiliation with an Imperial University.

The birth of the Institute was the product of an initiative by two prominent faculty members of Tokyo Imperial University College of Engineering, Inokuty Ariya (from Mechanical Engineering) and Seinen Yokota (from Naval Architecture); see Appendix C.4 for details. Prompted by growing awareness of aviation's importance, triggered by its successful use on WWI battlefields, they initiated the Commission for the Study of Aeronautics within the Naval Architecture division of Tokyo Imperial University in the fall of 1916, recruited two young recent top graduate engineers, and commenced research on aerodynamics and high-altitude engines using the basement storage room of the adjacent Faculty of Law as their lab (Suhara, 1961, p. 1). Concurrently, they proposed the establishment of the Institute of Aeronautics and its budget, which were enacted into law formally ordaining the Institute in affiliation with the College of Engineering two years later, in 1918.

A paragraph in the law establishing the Institute stipulated that its researchers were to be appointed by the Minister of Education from professors and assistant professors of Imperial Universities. This was a ground-breaking organizational innovation (Suhara, 1961, p. 2). Our data shows the Institute employed 62 engineering faculty members between 1918-1939. Many held exclusive appointments while retaining full status of Imperial Universities' core faculty. Such an arrangement meant independence from departments' hierarchies and no teaching obligations, setting the stage for scientific research *"to be looked upon as important a function of a university as education*" (Nakayama, 2009, p. 56).

Our identification strategy relies on the fact that the Institute, in accordance with its research profile, recruited mostly from the core engineering faculty in the divisions of Mechanical Engineering and Naval Architecture (also from the Physics division in the College of Science). Core faculty in those divisions could now be full-time employed at the Institute, partially or fully relieved of teaching obligations.[7] Thus, we can quantitatively assess the impact on faculty attraction and retention. The basic idea is that the prospect of being able to concentrate on research with little or no teaching duties should have made choosing Tokyo Imperial University engineering faculty jobs particularly attractive for graduates from the Naval Architecture and Mechanical Engineering divisions, relative to graduates from other divisions. Given the above timeline, and accounting for the anticipation effect, we use 1916 (the establishment year for the Commission) as the starting

[7] Teaching load was adjusted by hiring more temporal lecturers whose number increased in those divisions over time (see Figure C1 in the Appendix).

point in our empirical specification. We implement a difference-in-differences estimation: graduates from Naval Architecture and Mechanical Engineering comprise the treated group, while those from other divisions are the control group. Formally, we use the following specification to estimate the effect of the establishment of the Institute of Aeronautics at the individual level:

$$y_{it} = \sum_{s} \beta_s \times Treat_i \times 1(t = s) + \gamma_i + \gamma_t + \varepsilon_{it},$$

where y_{it} is an indicator equal to one if individual i is Tokyo Imperial University College of Engineering faculty in year t; $Treat_i$ is a dummy equal to one if individual i graduated from either Naval Architecture or Mechanical Engineering division and zero otherwise, interacted with the time dummy equal to one for each year; γ_i is the individual fixed effect; γ_t is time fixed effect; and ε_{it} is the error term.

To begin with, Figure 5 (top panel) depicts the effect of the Institute of Aeronautics in the aggregate time series. The time trends reveal that until 1915, the shares of graduates (all faculty and core faculty) who became faculty at the College of Engineering evolved in parallel between treated and control groups. Subsequently, the two trends diverge sharply. The top panel of Figure 6 presents the estimated individual level plot. Prior to Institute inception, there was no difference between the probability of joining Tokyo Imperial University engineering faculty by the graduates from treated and control divisions. After its inception, we see economically and statistically significant increase in the relative likelihood of becoming Tokyo Imperial University engineering faculty by graduates from Naval Architecture and Mechanical Engineering divisions as compared to graduates from all other divisions.

[Figures 5 and 6 around here]

The bottom panels of Figures 5 and 6 examine whether the Institute's establishment had a similar impact on faculty retention. Among the core engineering faculty in 1910, there is no difference in retention between treated and control divisions until about 1915, but after that, faculty who were graduates from the treated divisions were much more likely to stay as engineering faculty compared to all other graduates.

To rule out the alternative explanation that the Institute created higher pecuniary compensation for graduates of treated divisions, we compared the earnings trends (Figure 7) and found no significant difference in such trends between treated and control groups. Finally, since the Institute of Aeronautics enabled full-time research for Tokyo Imperial University engineering faculty only, we conducted placebo tests using the other three Imperial Universities (Kyoto, Kyushu & Tohoku); these tests ensure the relative increase in the likelihood of becoming faculty among graduates from Naval Architecture and Mechanical Engineering divisions did not simply reflect general trends in their importance. Appendix Figure C2 shows no significant difference in the faculty recruitment and retention rates of the two divisions relative to other divisions for these three universities.

[Figure 7 around here]

Taken together, the difference-in-differences and event-study evidence demonstrate that the establishment of the Institute of Aeronautics had a causal effect on both the attraction and retention of faculty in the affected divisions. Crucially, this effect operated through changes in the organization of academic work—specifically, the ability to concentrate on research with expanded scope and reduced teaching obligations—rather than through changes in pecuniary compensation. The Institute of Aeronautics thus illustrates how faculty-created organizational forms translated abstract gains in autonomy into concrete, research-oriented career opportunities, increasing academia's ability to attract and retain top talent precisely in domains of high and growing industrial relevance. This institutional mechanism provides the foundation for understanding why similar research institutes proliferated in subsequent years and why they became increasingly salient to actors beyond academia.

V.4.2. The Expansion of Research Scope through Academic Research Institutes

The Institute of Aeronautics was the first of several such institutes that proliferated across Imperial Universities, closely tracking the diversification of Japan's industrialization into materials, chemicals, pharmaceuticals, and electrical machinery-related technologies. At Tokyo Imperial University, the Institute of Seismology was established in 1925, following the devastating Great Kanto Earthquake of 1923, initiated by faculty from the Colleges of Engineering and Science who identified the need for sustained, fundamental research in earthquake science. One of the initiators, Kyoji Suehiro (professor of Naval Architecture), became its first director. At Tohoku Imperial University, the Institute of Material Research was formally inaugurated in 1919, growing out of faculty-led research in metallurgy and materials science, initially supported by private corporations. Similarly, the Institute for Chemical Research at Kyoto Imperial University, formally inaugurated in 1926, emerged from independent faculty research efforts in chemistry and chemical engineering (see

Appendix C.4). In each case, research institutes enabled inquiry that cut across disciplinary and industrial boundaries and emphasized long-term scientific problems rather than immediate production needs.

Academic research institutes were not limited to organizations formally affiliated with Imperial Universities. The Institute of Physical and Chemical Research (widely known as Riken) stands out as a particularly influential example of how research institutes expanded the scope of academic inquiry. Founded in 1917 as a private not-for-profit institution modeled after the German Kaiser Wilhelm Society (now the Max Planck Society), Riken was spearheaded by Imperial University faculty from its inception. Its transformation into a major center of industry-related basic research accelerated after 1921, when Masatoshi Okochi—an engineering professor at Tokyo Imperial University and a prolific inventor—was appointed as its third director. Okochi reorganized Riken into a system of independent laboratories, each led by academic faculty with full autonomy over research topics, personnel, and budgets. This structure allowed faculty to pursue exploratory research agendas spanning multiple technological domains while training cohorts of young researchers, many of whom were recent Imperial University graduates or even students. Thirty-three core faculty members in our data headed Riken laboratories during the sample period, and a substantial majority were active inventors.

The impact of this organizational transformation can be examined quantitatively using patent data. Beyond simple differences in the propensity to patent, research institutes altered the *nature* of innovative output generated by academic faculty. Appendix Figure A5 shows that while the private sector accounted for the largest absolute number of patents, patent output per graduate in academia increased sharply after World War I. By the 1930s, patenting per graduate in academia exceeded that in the private sector. However, the most distinctive feature of academic research was not intensity alone, but the breadth of technological exploration it enabled.

To quantitatively capture this dimension, we construct a proxy for the scope of research using patent data matched to inventors' employers. Specifically, we calculate Shannon's entropy measure of patent subclass diversity for each patenting organization, separately by inventors' graduation divisions to ensure comparisons among individuals with similar technical backgrounds. [8] We then regress this entropy measure on indicators for

[8] Shannon's entropy, $H = -\sum_{i=1}^{S} p_i ln(p_i)$ where p_i is the proportion of category i and S is the total number of categories, is widely used as a measure of diversity in various branches of sciences, including social sciences. In constructing this measure, we made use of patent classification provided by the Japanese Patent Office in which each patent was assigned its technology class (*Rui,* in Japanese*,* which can be mapped into a three-digit class in the IPC classification), as well as a subclass and group (which can be mapped into a four-digit subclass in the IPC classification and a four-digit-

employment in academia (Imperial Universities and Riken) and in government or military institutions, using private-sector firms as the baseline.

Table 3 shows patents produced by inventors employed in academia exhibit substantially greater technological diversity than those produced in private firms or government institutions. In column (1), patents associated with academia have nearly 90 percent higher entropy relative to the private-sector baseline, while patents produced by government-employed inventors are statistically indistinguishable from those of private firms. In columns (2)–(4), we progressively restrict the private-sector baseline to diversified firms and to firms with highly diverse patent portfolios. Although the magnitude of the difference declines, academic research remains significantly more diverse relative to the most technologically broad private firms. These findings are robust to alternative measures of diversity using patent classes or main groups rather than subclasses.

[Table 3 around here]

Taken together, this evidence indicates that academic research institutes fundamentally altered the scope of research feasible within academia. In contrast to firm and government laboratories, academic research institutes enabled faculty to pursue broader and more exploratory research agendas with potential relevance across multiple industries. By expanding the scope of inquiry rather than merely increasing research effort, these institutes enhanced the non-pecuniary attractiveness of academic careers and laid the groundwork for the strategic responses by industry and the state examined in the next section.

V.5 Strategic Complementarities and Cross-Sector Alignment from Institution-Building Efforts

The expansion of research scope enabled by academic research institutes not only increased the non-pecuniary attractiveness of careers in the academic sector but also reshaped the strategic environment facing the private and government sector. Even as firms competed with academia for top scientific and engineering talent, faculty-created research institutes generated new opportunities for collaboration that aligned with firms' strategic needs during Japan's industrialization.

At the onset of industrialization, Japan relied heavily on foreign technology transfer—often described as "borrowed technology"—to support industrial development. Over time, however, domestic invention

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plus-digits main group in the IPC classification) (see Hatsumei Kyokai, 1963). We use patent subclass assignments in the main specification below, but very similar results can be obtained by using class and group classifications.

increased sharply, particularly after World War I and especially in technological domains central to the Second Industrial Revolution, such as electricity, chemicals, and scientific instruments (Nicholas, 2011). This increase in domestic research activity was broad-based and not confined to academia (Nicholas, 2011; see also Figure A4 in the Appendix). Yet, Table 3 above showed important differences in the scope of research conducted across sectors, which is also corroborated by qualitative evidence provided by historians. Research labs set up by private firms were narrowly defined to respond to urgent specific requests from production and operations, and did not provide opportunities to pursue a broader research agenda (Ishii, 2021, pp. 192-193). Government research institutes prescribed research agenda aligned with the priorities of the administrative unit in charge; they were also subject to transfers of jurisdiction, reorganizations, and personnel cuts (Kamatani, 2006, p. 85). As a result, these research labs were unable to address the strategic gap in accessing domestically created broad, exploratory, and high-risk basic research with long-term technological implications.

The emergence of high-quality, industry-relevant academic research institutes altered this calculus. By expanding the scope of research feasible within academia, these institutes enabled firms to shift from reliance on imported foreign patents toward sourcing foundational technologies domestically. Importantly, this was not a passive process driven solely by government intervention. Historical evidence indicates that firms actively recognized and responded to the new organizational capabilities created within academia.

One channel through which this alignment unfolded was the direct sponsorship of faculty-led research. At Tohoku Imperial University, the Institute of Material Research emerged from two faculty-initiated projects in organic chemistry and metal physics that received early support from Sankyo and Sumitomo corporations, respectively (Appendix C.4). The success of these projects—reflected in extensive patenting, including nearly 100 global patents—generated sustained flows of donations from a wide range of private firms (Appendix Table C2). The Institute for Chemical Research at Kyoto Imperial University followed a similar trajectory, with faculty-driven research agendas attracting long-term corporate support. In these cases, firms did not merely finance research ex ante; they selectively committed resources in response to demonstrated scientific capability and technological promise.

A parallel dynamic unfolded at the Institute of Physical and Chemical Research (Riken). Founded in 1917 as a private not-for-profit institution modeled after the German Kaiser Wilhelm Society, Riken was spearheaded by Imperial University faculty from the outset. Its creation itself reflected strategic foresight on the part of industrial leaders. Jokichi Takamine, the New York–based founder of Sankyo Corporation, played a central role in mobilizing support for the institute, prompting Eiichi Shibusawa—the "father of Japanese capitalism"—to organize a founding committee (Riken Seishi, 88 nen, 2005). When Riken was established, the vast majority of its initial funding came from private industry, with donors spanning all major Japanese business groups (Appendix Table C4). Although the government later provided annual subsidies, private donations still accounted for nearly 40 percent of Riken's total capital funding through the late 1930s (Appendix Table C3). These patterns underscore that firms deliberately chose to support academic research institutes as a strategic complement to their own research activities.

Patent data further illustrate the strengthening of academic–industry linkages over time. Figure 8 shows the evolution of patent assignments for Tokyo Imperial University College of Engineering graduates who were members of Imperial University faculty. In early years, most patents were assigned to individual academics but over time patents increasingly involved private firms, either through direct assignment or through co-invention with firm-employed researchers. Particularly striking is the growth in patents assigned to academic research institutes themselves, which accounted for roughly one-quarter of faculty patents in 1919–1923 and nearly one-half in subsequent years.

[Figure 8 around here]

These patterns reflect the contractual and governance arrangements governing sponsored research. Under prevailing rules (Appendix C.4), patents arising from sponsored research were assigned to the institute, while sponsors were promptly notified and granted the option to negotiate exclusive usage rights for specified periods. This structure enabled firms to outsource high-risk basic research to academic institutes while retaining downstream options for exclusivity and commercialization. For academics, these arrangements preserved autonomy and bargaining power, as patent ownership initially remained within the academic organization. Over time, revenues generated from such patents became an important source of research funding. At Riken, for example, patent revenues accounted for approximately half of total revenues by the late 1930s, substantially reducing reliance on government subsidies and private sector support (Appendix Table C5).

Beyond sponsored research, firms also strategically engaged academic faculty as consultants and recruiters. The career of Kyoji Suehiro—a top graduate in Naval Architecture in 1900 and the first director of the Institute of Seismology—illustrates this dynamic (Appendix C.3). Although Suehiro left Mitsubishi Shipbuilding shortly after graduation to pursue an academic career, the firm maintained a long-term strategic relationship with him. As Suehiro rose to prominence and became a central advisor to students, Mitsubishi increased its recruitment of Naval Architecture graduates through structured training placements. Suehiro also advised Mitsubishi in establishing its own research institute and served as its first director while retaining his academic position. Most of his patents were ultimately assigned to Mitsubishi. Similar cases of faculty–firm collaboration that did not require faculty to exit academia are documented in Appendix C.3.

Taken together, these patterns reveal a set of strategic complementarities across academic, private and public sectors. Faculty-led research institutes increased the scope and attractiveness of academic careers, enabling academia to retain top talent despite widening wage gaps with industry. At the same time, firms strategically chose to support and engage with these institutes to access broad, exploratory research, senior scientific expertise, and pipelines of emerging talent—essentially, they also benefited from non-pecuniary payoffs in academia, which allowed them not to bear full costs of maintaining large, high-risk basic research programs. Academic research institutes thus emerged as a distinctive organizational form that facilitated collaboration across sectors, aligning non-pecuniary incentives for talent with the strategic objectives of firms and the developmental goals of the state.

VI. THE EVOLUTION OF INDIVIDUAL CHOICES: QUANTITATIVE ESTIMATION

In this section we employ a structural model to quantitatively gauge how the evolution of the academic environment toward focusing on faculty-driven research led to increased non-pecuniary attractiveness of academic jobs, endogenously giving rise to Japan's own "scientific ethos."

Beginning with the seminal work by Roy (1951), scholars have recognized the important role played by selection in the distribution of earnings across occupations. Rather than randomly allocating to different occupations, individuals actively select occupations that offer "*the greatest reward*" (Roy, 1951, p. 141). To use Roy's illustrative example, if writing scientific papers provided earnings second to fishing, it would follow that "*if a high enough level of earnings is chosen, there will be more fishermen with incomes greater than this than scientists*" (*ibid.*, p. 143). Such pecuniary motivations are at play in our setting as well, as Section V.1 illustrates an increasing earnings gap between industry and academia. However, Section IV highlights that top talent nonetheless flowed into academia, even at an increasing rate, during this period. While the historical narrative in Section V showcased increases in non-pecuniary attractiveness, these changes could be internalized by subsequent graduate cohorts and reflected in changing utility across generations. We capture this aspect in the model by including cohort trend as a variable in the set of individual characteristics affecting non-pecuniary preferences. Furthermore, in recognition of the importance of the establishment of the Institute of Aeronautics shown in Section V.4.1, we include a dummy equal to one for graduates from Mechanical Engineering and Naval Architecture divisions interacted with observation years after 1916 in some specifications.

One interpretation of Roy's selection model is that top graduates kept choosing academia because their potential alternative earnings would be even lower in industry, due to lower returns for their talent in industry. An alternative interpretation is that Roy's "rewards" should include not just monetary earnings, but also non-pecuniary payoffs. The institutional evolution and the causal identification exercise in Section V.4 suggest such non-pecuniary payoffs (attractiveness of faculty jobs especially through increased opportunities for research) were increasing over time. This second interpretation implies the trend observed in Section IV may be driven by selection based on increasing non-pecuniary rewards that offset the growing wage gap for top talent. To adjudicate between these two explanations, we use earnings and jobs data of top graduates to conduct structural estimations, employing the framework from the commonly used dynamic model of occupational choice (cf. Keane and Wolpin 1997; Traiberman, 2019) as informed by the historical account above.

VI.1 Non-Mathematical Overview of the Model

In the simplest occupation selection framework, individuals select into an occupation which offers the highest rewards at any given point in time. In our model, workers' rewards from each occupation are a function of not just earnings (pecuniary compensation) but also non-pecuniary motivations. Put differently, individuals maximize overall utility. The model mechanics allow us to structurally estimate the unobserved non-pecuniary rewards based on observed earnings and occupational choices and determine counterfactual earnings for the occupation that was not chosen.

At the start of each period during the (finite) lifecycle, the individual is employed in a particular sector chosen in the previous period and is exposed to a random, individual-specific shock affecting his total utility. He then chooses a new occupation (including the option to stay in the same sector) based on the highest utility rewards from that period onward.[9] If switching occupations was costless, the individual would always choose the sector which generates the highest utility at each point in time. To accommodate the reality of occupation switching costs,[10] we adopt a recurring occupational choice model: in each period, the individual selects into an occupation by comparing the menu of payoffs against the costs of switching occupations (Traiberman, 2019).

The following assumptions underpin our structural estimation. First, the costs of switching occupations are a function of accumulated human capital. Second, from the individual's point of view, structural conditions in human capital markets are taken as given. Third, recurring occupational choice with time-dependent switching costs implies individuals are forward looking—in contrast to dynamic structural estimation models where individuals know all relevant prices and functions (e.g., Keane and Wolpin, 1997), we assume that while individuals may not be able to forecast the whole time paths of their potential future earnings in each sector, they do make (on average correct) predictions about time trends in their individual-specific earnings when making recurring occupational choices at any point in time. Fourth, non-pecuniary components of the utility function are assumed to be individual-specific and time-invariant, apart from period-specific shocks. Fifth, we assume part of the individual's non-pecuniary utility is a function of observed individual characteristics.

To sum up, individuals exercise a forward-looking recurring occupational choice by comparing total (utility) payoffs in each sector against switching costs. The panel data of observed earnings and occupational choices allows us to estimate, for each period, the counterfactual earning potential in different sectors and the unobserved non-pecuniary payoffs, in addition to quantifying the role played by observed individual characteristics, such as being a member of a particular graduating cohort, or an early academic achiever.

VI.2 The Model: Formal Description

Time is discrete. Each graduate i has a finite decision horizon $a \in \{0, \dots, A\}$. At each age a, an individual chooses among three occupational options: working in academia (Imperial Universities) $(j = 1)$, in industry

[9] Our use of these pronouns reflects the fact that graduates during this cultural time period in Japan were all male.
[10] "*In the short run, … workers will not switch jobs just because their earnings are likely to be increased but, if they are rational, they will consider the costs incurred by such a change and the differences in the 'net advantages' of alternative occupations*" (Roy, 1951, p. 145).

(the private sector) ($j = 2$), or government (including the military) ($j = 3$).[11] Individuals receive utility from both earnings $w_{ij}(a)$ and the non-pecuniary rewards, comprised of (i) age-invariant utility $\beta_j X_i + \omega_{ij}$, where X_i are observable individual characteristics noted below and ω_{ij} is an unobserved component, and (ii) age-variant utility shocks $\rho\varepsilon_{ij}(a)$, if they choose occupation j. The utility from earnings is described by a standard constant relative risk aversion (CRRA) utility function. Individuals incur a job switching cost $c_j(a)$ each time they move to occupation j from another occupation. We denote the occupation choice at age a by an indicator $d_{ij}(a)$ (equal to 1 if occupation j is chosen and 0 otherwise). Then, the instantaneous utility for an individual of age a consisting of non-random flow of utility, $u_{ij}(a)$, and additively separable utility shocks, $\rho\varepsilon_{ij}(a)$, is:

$$U_{ij}(a) = \underbrace{\tfrac{[w_{ij}(a)]^{1-\gamma}}{1-\gamma} - c_j(a)[1 - d_{ij}(a-1)] + \beta_j X_i + \omega_{ij}}_{u_{ij}(a)} + \rho\varepsilon_{ij}(a), \tag{1}$$

for each occupation j, where ρ is a scaling parameter and $\varepsilon_{ij}(a)$ is independent and identically distributed across individuals and over time and follows the Type I extreme value distribution $G(\varepsilon)$.

The non-pecuniary part $\beta_j X_i$ in (1) is the critical element linking the structural model to the historical examination in the previous section. As mentioned, we capture the evolutionary nature of changes by including cohort numbers (trend) as a variable in the set of individual characteristics X_i, taking values from one (the 1879 cohort) to forty (the 1918 cohort) for members of each graduation cohort. Larger numbers are thus associated with graduating later in the sample; hence, a positive coefficient on this variable would imply higher marginal effect of non-pecuniary payoffs (captured by the preference parameter β_j) for an average member of a later cohort relative to an earlier cohort. In addition, the set of X_i includes several other variables that may have affected non-pecuniary payoffs from academic jobs based on the historical evidence. First, as also mentioned, we include a dummy equal to one for graduates from Mechanical Engineering and Naval Architecture divisions interacted with observation years after 1916.[12] Furthermore, to account for the possibility that early academic

[11] As in other occupational choice models, Keane and Wolpin (1997) assume the fourth option of staying at home, which includes being unemployed. Our data do not allow us to distinguish between being unemployed and missing data, so we treat observations with no employer data as missing. Of note, top-ranked graduates of the Imperial University were a scarce resource in high demand in Japan at that time, so unemployment was an unlikely event.

[12] When estimating and simulating the model, the effect of the establishment of the Institute of Aeronautics is treated as an unexpected change in the non-pecuniary rewards after 1916 for graduates from treated divisions. See Appendix D for the details of the assumptions behind the model derivation.

achievement could be correlated with the preference (non-pecuniary payoff) for academia, we include the dummy equal to one if a top graduate was designated as an honor student at the end of his second year, as well as the dummy equal to one if the student was ranked at the top of his class at the end of the second year.[13] Since utility is additive invariant, we normalize the non-pecuniary utility in the private sector to zero, so that $\beta_j X_i + \omega_{ij}$ represents the value relative to the private sector.

We model the (logged) wage process for individual i in sector j as follows:

$$\ln w_{ij}(a) = b_{j1} + b_{j2}a + b_{j3}a^2 + b_{j4}t + \nu_{ij} + \sigma_j \varsigma_{ij}(a),$$

where ν_{ij} is an individual-specific earning potential in sector j (with mean of 0) and $\{\varsigma_{ij}(a)\}_{j=1}^{3}$ are *ex post* idiosyncratic earning shocks that depend on age a and follow joint standard normal distribution $N(0, I)$ independently. We assume individuals cannot observe these idiosyncratic shocks at the time occupation choices are made in each period. We also assume a log-linear job switching cost function, and allow for individuals of different ages to face different frictions (e.g., the cost of changing a job can be higher for older individuals):

$$\ln c_j(a) = c_{j1} + c_{j2}a + c_{j3}a^2.$$

At each age a, individuals maximize expected present value of remaining lifetime utility. Denoting the individual state space by $s_i(a) = \{a,\ \{d_{ij}(a-1),\ \omega_{ij},\ \nu_{ij}\}_{j=1}^{3}\}$, the value function is the conditional expectation of current and future utility flows satisfying the following Bellman equation:

$$V_i(s_i(a)) = \max_{d_{ij}(a)} \ E\left[u_{ij}(a) + \rho\varepsilon_{ij}(a) + \delta \int V_i(s_i(a+1)) dG(\varepsilon) \middle| s_i(a)\right],$$

where δ is the discount factor and the integration is over $\varepsilon_{ij}(a)$. The expectation operator is over the distributions of current and future $\varsigma_{ij}(a)$, conditional on the individual state space $s_i(a)$. Following dynamic discrete choice models (Rust, 1987), with the distributional assumption of $\varepsilon_{ij}(a)$, we derive the conditional

[13] As mentioned in Section III.1, our earnings data are on top-ranked graduates. Therefore, there is no variation in graduation rankings within the sample used for structural estimation. Among those top-ranked graduates, we further identify students who were already ranked at the top of their cohorts at the end of the second year as well as "honor students" (*tokutai gakusei*) who were designated by the College Deans based on academic achievement and exemplary behavior and received tuition waivers (*Tokyo Daigaku Hyakunenshi,* 1997, Vol. 7, p. 633). Those honor students represent a subsample comprising about half of all eventual top graduates.

sector choice probability $P[d_{ij}(a) = 1 | s_i(a)]$ in a closed form (Appendix D). Given individual state variables, unobserved non-pecuniary gains and earning potential, we then derive the joint distribution of earnings and occupation choice from the model and estimate parameter values by maximum likelihood.

VI.3 Estimation of the Model

We estimate the model using data on top graduates, $i = 1, \dots, N$, that consists of the set of occupation choices and earnings, $\{d_{ij}(a),\ w_i(a)\}$. In theory, everyone has their own idiosyncratic earnings potential and non-pecuniary payoff, but identifying and estimating all those parameters for each individual separately is generally difficult and computationally not feasible. We follow the common approach in the literature (Keane and Wolpin, 1997) and categorize individuals into Q types, conditional on their observable characteristics, indexed by q. In this version of the model, we categorize them into four categories. We set the discount factor δ to 0.95. Since the risk aversion parameter is generally difficult to estimate precisely in a complex model, we set the value of parameter γ in the CRRA part of the utility function equal to 1.5 (using the point estimate in Eckstein, Keane, and Lifshitz, 2019), although the estimation results are robust to choosing other reasonable values. Thus, the parameters we estimate are collected into three sets: the set of parameters that are invariant across types, θ, the set of unobserved heterogeneity, λ_q, and the proportion of the q-th type in the population, π_q. We denote the probability of being type q conditional on individual initial values of the state variables by π_{iq}. Then, the likelihood of the observed data can be written as a finite mixture of type-specific likelihoods:

$$L(\theta) = \prod_{i=1}^{N} \sum_{q=1}^{Q} \pi_{iq} \left\{ \prod_{a=1}^{A} P[d_{ij}(a) = 1 | s_i(a), \theta, U_q]\, f[w_{ij}(a) | s_i(a), \theta, \lambda_q] \right\},$$

where $f(\cdot)$ is the log normal probability density. We use the sequential EM (Expectation-Maximization) algorithm as in Arcidiacono and Jones (2003) to estimate the underlying parameters. Specifically, we first estimate the posterior probabilities of each graduate being assigned to each of the four types π_{iq}, conditional on the given type-specific set of parameters. The next step in the estimation procedure is to estimate the parameters θ and λ_q (parameters invariant across types and unobserved heterogeneity) governing occupational choices and earnings via maximum likelihood, treating the conditional probability of being each type π_{iq} as given. The estimation then iterates these two steps until it converges to the probabilities of each type and the parameter set that fit the empirical data.[14] Finally, standard errors are calculated using a parametric bootstrap procedure with 100 replications (See Appendix D for sequential EM algorithm and bootstrap procedure).

We estimate the model in five specifications which differ only in what is included in the set of individual-specific characteristics X_i affecting the non-pecuniary utility component: specification (1) only includes the cohort trend; specification (2) includes the cohort trend and the dummy capturing the establishment of the Institute of Aeronautics in 1916, interacted with Mechanical Engineering and Naval Architecture divisions; specification (3) includes the cohort trend and the dummy capturing if the top graduate was also an honor student; specification (4) includes the cohort trend and the dummy capturing if the top graduate was also a top student after the second year; and, finally, specification (5) includes all the above individual-specific characteristics X_i that vary across individuals and time, affecting their non-pecuniary preferences.

VI.4 Estimation Results

The estimation results are presented in Table 3 and Tables A3-A6 in the Appendix. Estimated earning parameters (Table A3) present the picture consistent with the reduced-form estimation results in Table 1 above.

Table 3 provides coefficient estimates of β_j, measuring the impact of our variables of interest. Recall that non-pecuniary payoff for industry is normalized to zero, so the estimated parameters are interpreted relative to the private sector. The estimated coefficient on the cohort trend (graduation cohort number variable) is positive and statistically highly significant in specification (1) where we do not include any other individual characteristics. As more variables capturing other individual characteristics (some of which are partially correlated with the cohort trend) are added in specifications (2)-(5), this coefficient declines in magnitude but remains economically significant in all specifications and statistically significant in specifications (2)-(4).

[Table 3 around here]

Thus, the estimation results indicate that top graduates from later cohorts had higher non-pecuniary "payoffs" in an academic career compared to top graduates from earlier cohorts, and these potentially offset the increasing salary gaps with the private sector. These estimation results are consistent with the conjecture

[14] Recent literature (e.g., Traiberman, 2019) often utilizes the finite dependence property to recover the flow utility parameters (Arcidiacono and Miller, 2011) by estimating the conditional choice probability directly from the data. We don't take this approach and calculate the full likelihood to estimate the parameters because of insufficient observations that satisfy the finite dependence property to obtain the precise estimates of the parameters.

that successful institution-building measures, especially the increased focus on research may be a causal factor. In particular, the coefficient on the Institute of Aeronautics variable, which was shown to have both economically and statistically significant causal impact in the previous section, is large in magnitude although the standard errors are high, presumably because of the limited number of observations in the two affected divisions. All in all, it is hard to think of another reason why top graduates from later cohorts would still choose academic careers, despite the private sector offering increasingly better pecuniary compensation.[15]

The estimated coefficient on the honor student dummy in specification (3) is positive, although statistically not significant at the conventional levels. The point estimate, however, is large in magnitude, implying that honor students had about 50 percent higher non-pecuniary payoff in academia compared to all top graduates, although the standard errors are high. Similar estimates are obtained in specification (4) where we include the top of class at the end of second year dummy. When we include both dummies in the full-model specification (5), the estimated coefficient on the honor student dummy is twice the magnitude of the estimated coefficient on the top students at the end of the second year dummy. Since only truly outstanding top students were designated as "honor" students they represent the highest early academic achievers. Thus, early top achievement may have been a major factor leading such achievers to become more interested in an academic career.

The estimates of the parameters in the switching cost function are presented in Table A4. We can see that such costs also had a significant impact on individual mobility across sectors (see Appendix D.4 for how to separately identify the effects of non-pecuniary payoffs vs. switching costs). The parameter estimates suggest that moving to academia or the public/military sector may be more costly for older individuals, while switching costs into the private sector may not depend on age that much.

The distributions of pecuniary and non-pecuniary components' heterogeneity across the four types are presented in Tables A5-A6. Note that earning heterogeneity across the four types is conditional on individual age and time trend, and the non-pecuniary component heterogeneity is conditional on graduation cohort and other observed individual-level characteristics X_i above, which are our focus of interest. We also conducted a "sanity check" of the outcomes of our structural estimations using reduced-form specification and confirmed

[15] As noted by Iwata (2021, p. 265), "*It may sound ironic, but the decline in [pecuniary] attractiveness of professorial jobs in Imperial Universities may have been responsible for driving individuals who worshipped money ("haikinshugisha") away from the academic profession. …* [In the Taisho era (started in 1912—authors)], *a homogeneous academic community, sharing the research mindset was finally born.*"

that, consistent with the findings from structural estimations that although monetary compensation may have been important in choosing careers in academia early on, increasing non-pecuniary motivation, had a much bigger role in later cohorts and among top early achievers (Appendix D.6).

VII. COUNTERFACTUAL SIMULATION

Could Imperial Universities recruit enough talented faculty even without the persistent increase in non-pecuniary components? To examine this, we implement forward simulation exercises using the estimated parameters in the previous section. First, we check whether our estimated model provides a good fit to the actual occupation choice patterns in the data. Second, we simulate a counterfactual scenario to examine the role of the evolution of non-pecuniary compensation in talent allocation. The details are described in Appendix D.4.

VII.1 Model Fit

Figure 9 shows how well the model simulation fits the actual patterns of the number of graduates who chose to work in academia over the years used in the structural estimation (1902-1933) when using the estimated parameters in the previous section. The black line with circles shows the shares of individuals in academia by year in the actual data, while the red line with diamonds represents the simulated corresponding shares. Figure AX in Appendix AX shows the corresponding patterns of the shares of individuals in private and public sectors by year. The shaded area represents the 95% interquartile range across 100 simulations.

[Figure 9 around here]

As seen in these figures, the simulation using the estimated parameters fits the dynamic patterns of the graduates' share by year in each sector reasonably well, especially for the share in academia. While the model underestimates the share in the private sector and overestimates the share in the public sector in later periods, the time trends are similar to the actual data and capture the increasing (decreasing) trends in the private (public) sector. Figure AX in Appendix also shows the logged earnings profiles in the simulation using estimated parameters fit actual earnings profiles in each sector reasonably well.

VII.2 Counterfactual Scenarios Without the Evolution of Academia

To examine what could have happened without a persistent increase in non-pecuniary compensation in academia, we simulate the full model (Table 2, model 5) by replacing the coefficients β_j by counterfactual parameter values. Specifically, we set all coefficients in academia to zero. The blue line (with triangles) in Figure

9 shows the simulated time series of the aggregate share of top-ranked graduates at Imperial Universities, and the shaded area represents the 95% interquartile range across 100 simulations. Figure A6 in the Appendix shows the corresponding counterfactual shares of individuals in private and public sectors by year.

The counterfactual simulation illustrates the importance of non-pecuniary payoffs in academia. It predicts not only the decline in levels of the share of top graduates choosing academia, but also the decreasing trend over time. While some graduates may have moved to the public sector in those counterfactual scenarios, graduates in the later cohorts would be more attracted by higher pecuniary incentives in the private sector, had the academic sector not increasingly provided non-pecuniary benefits to offset the growing earnings gap. In our simulations, only 60 percent of top graduates who were actually Imperial University faculty would still be in academia at the end of the estimation period (in 1933); most of those would have chosen the private sector instead. In this counterfactual scenario, the private sector would not need to pay the "wage premium" to attract the same fraction of top graduates as in the actual case. According to the utility function assumed in our model, the estimated premium varies by cohort and other individual-specific characteristics, but we can calculate it for an average member in various cohorts using the procedure described in Appendix D.5. Such a premium is estimated to be 15.3 percent for the cohort that graduated in 1890, increasing to almost 29.7 percent for the 1900 cohort, and to 43.6 percent for the 1910 cohort. Please see Appendix D.5 for more details.

One caveat in the scenarios above is that we do not consider general equilibrium effects; that is, we implicitly assume that the compensation offered to top graduates in the private sector would not change despite more of them choosing careers in industry. Since the private sector was comprised of many competitive firms and top graduates were in very high demand, such effects may not be large (increased supply of top graduates may have simply displaced some lower-ability graduates from better firms without affecting their compensation too much). Inasmuch as general equilibrium effects would manifest themselves, our counterfactual simulations may somewhat overestimate the decline in the share of top graduates choosing academic careers and the increase in the counterfactual earnings of those who would still choose academic careers among them.

VIII. DISCUSSION & CONCLUSION

This study examined how academic institutions evolved to attract and retain top scientific talent during Japan's industrialization, and how those institutional changes shaped the allocation of human capital across academia, industry and the public sector. Using a combination of historical analysis, causal evidence and structural estimation, we showed that academic careers became increasingly attractive to top-ranked engineers despite a growing earnings gap with industry. This outcome was driven by changes in the organization of academic work that increased the non-pecuniary returns to academic employment, *i.e.,* the creation of the now taken-for granted academic "social ethos" (Merton, 1973) that privileges autonomy in governance structures and research as part of the core academic mission.

A central contribution of the paper is to demonstrate how these changes came about. Rather than emerging as a byproduct of government policy, the institutional features that later characterized Japanese academia were shaped through sustained, faculty-led initiatives. By expanding academic autonomy, redefining professional purpose around research, and creating research institutes as new organizational forms, faculty altered both the nature of academic careers and the kinds of research that universities could support. Causal evidence from the establishment of the Institute of Aeronautics confirms that these institutional innovations directly increased faculty attraction and retention, independent of compensation effects. Structural estimates further show that non-pecuniary payoffs rose across cohorts and played a decisive role in occupational choice.

Importantly, the consequences of these academic institutional changes extended beyond the university. As research institutes expanded the scope and orientation of academic research, they reshaped how other organizations approached innovation and talent. Government authorities adapted governance and funding arrangements in response to faculty-led reforms, while private firms adjusted how they accessed scientific expertise, sourced foundational technologies, and organized research activities. These responses did not eliminate competition for talent, but they altered its form. Over time, academia and industry came to occupy differentiated yet complementary roles in the production and application of new knowledge.

Boundary Conditions and Future Research

The findings of this study are grounded in a specific historical and institutional context, which suggests several boundary conditions. First, the analysis focuses on a period in which academic institutions were still forming and professional norms had not yet fully crystallized. The scope for institutional experimentation—and for faculty to shape governance, purpose, and organizational form—may be greater in such formative environments than in mature systems with entrenched rules and stakeholder expectations. Second, Japan's Imperial Universities operated within a public system characterized by centralized authority, cultural constraints on pecuniary negotiation, and strong national development objectives. These features shaped both the constraints faced by faculty and the channels through which institutional change occurred. While similar dynamics may arise in other settings, the specific pathways through which institutions evolve are likely to depend on prevailing political, cultural, and economic conditions. Finally, the study focuses on science and engineering fields in which research activities have clear potential for broad technological spillovers. The mechanisms identified here may operate differently in disciplines where research is less cumulative, less capital intensive, or less closely tied to industrial application.

These boundary conditions point to several directions for future research. One avenue is to examine whether similar patterns of faculty-led institution building emerge in other historical or contemporary settings, including private universities, nonprofit research organizations, or emerging innovation systems in developing economies. Comparative studies across countries or periods could help identify which institutional features facilitate or constrain the kind of organizational experimentation documented here. A second direction is to explore heterogeneity within academia itself—for example, how differences across disciplines, career stages, or internal governance structures shape the ability of faculty to influence institutional evolution. Finally, future work could examine how the dynamics identified in this study play out once institutions mature: whether early complementarities between academia and industry persist, attenuate, or transform as research systems scale and professional norms solidify. Such work would further illuminate how institutional trajectories shape long-run patterns of innovation and talent allocation.

Contributions and Managerial Relevance

Our findings speak to several literature streams. First, they extend work on scientific labor markets by moving beyond static analyses of mature systems (Agarwal and Ohyama, 2013; Ehrenberg, 1991; Roach and Sauermann, 2010; Sauermann and Roach, 2017) to show how non-pecuniary incentives and academic "social ethos" are endogenously produced through institutional change. Here, our structural estimations also revealed positive correlation between academic achievement during college and non-pecuniary payoffs in academic jobs after graduation. While the logic of winner-take-all contests suggests a positive correlation between ability and non-pecuniary preferences for academia (Stephan, 1996), this correlation is largely treated as a nuisance parameter (Agarwal and Ohyama, 2013; Boudou, 2024; Stern, 2004). Our study is consistent with the recent exception (Roach and Sauermann (2017): their empirical analysis shows students who perceive their research ability as increased over the course of their PhD studies are less likely to lose interest in academic careers.

Second, our study contributes to research on the organization of innovation by illustrating how academic purpose and research orientation can evolve in tandem with industrial needs, rather than being fixed or strictly separated. Contemporary studies in the US context highlight division of labor between academia and industry in the innovative process (Arora and Gambardella, 1994). The US, however, represents the institutional context shaped by the *assumption* that basic and applied research are ends in a linear continuum where academia needs to compensate for industry's underinvestment in basic research, as articulated by Vannever Bush (Bush, 1945) and echoed in later theories (e.g., Dasgupta and David, 1994). In contrast to linear models that treat basic and applied research as sequential stages (Bush, 1945; Dasgupta and David, 1994), the Japanese experience—and the institutional innovation of academic research institutes—highlights conditions under which research activities in academia and industry become mutually reinforcing, consistent with the logic of Pasteur's quadrant (Stokes, 1997), and assortative matching between researchers and firms in academic-industry relationships (Mindruta, 2013) to enable complementarities between cross-sector basic (science) and applied (technology) research. This resulted in Imperial Universities' faculty being among the most prolific inventors, especially in the later part of our sample, suggesting that theoretical frameworks of additive production functions between basic and applied research functions in academia (e.g, Agarwal and Ohyama, 2013) may need modification when examining contexts where industry and academic science are integrated for novel discoveries and technologies.

Third and relatedly, the study informs work on growth and development resulting from sectoral complementarities in academia and industry (Nelson & Rosenberg, 1993; Romer, 1990). While prior research has highlighted the importance of educated engineers for industrialization (Maloney and Caicedo, 2022; Murphy, Shleifer, and Vishny, 1991), less attention has been paid to how institutions shape their allocation between academic and industrial careers. Our findings imply that rather than a "versus" mindset regarding allocation of top engineering talent between industry and academia, endogenous creation of institutions that cater to pecuniary and non-pecuniary preferences of top talent can be particularly important for the nature and magnitude of spillovers across sectors, thus affecting both the direction and the impact of innovation activity.

Finally, we uncovered the evolutionary mechanisms shaping academic institutions that were critical co-requisites to industrialization in Japan's ascension to developed economy status. Here, our study highlights that the evolution of non-pecuniary attractiveness of academic jobs was driven by incumbent faculty's proactive efforts to shape the institutional rules of the game (Gavetti, et al., 2017). In turn, this was matched by the Meiji-Taisho era government and university administration demonstrating flexibility and recognition of the critical long-term need of making faculty jobs attractive to top talent as they undertook the task of building strong national innovation system and industrial potential. The resulting evolution of the "social ethos" in academia in Japan was thus consistent with the culture and governance of liberal societies as described by Merton (1938),[16] and in stark contrast to Germany's hostility in the 1930s toward science that *"rests upon the feeling of incompatibility between the sentiments embodied in the scientific ethos and those found in other institutions"* (*ibid*, p. 322). We believe this has profound policy implications for our own day. Regardless of whether academic institutions need to be developed or maintained, our study highlights that academia's ability to be an innovation engine in modern day economies relies on its institutions representing autonomy and freedom, so that its scientific ethos is preserved against "*logical and non-logical processes [that]…curtail scientific activity" (ibid,* p. 322*)* and "*expansion of political or religious or economic authority [that] limits the autonomy of the scientist (ibid,* p. 336)," regardless of whether these processes emanate from sources within or outside academia.

In summary, the historical evidence presented here also carries implications for contemporary organizational leaders and policymakers. For firms competing for scientific and engineering talent, the findings highlight the limits of wage-based competition alone. Even in environments where industry compensation substantially exceeds academic pay, organizations may benefit from engaging with external research platforms that offer autonomy, scope, and long-horizon inquiry—features that are difficult to replicate internally without substantial cost or through higher wages alone. These insights speak directly to contemporary debates on

[16] As Merton (1938, p. 327) noted of liberal societies, "*Science, which has acquired a considerable degree of autonomy and has evolved an institutional complex* [represents]…*sentiments embodied in the ethos of science—characterized by such terms as intellectual honesty, integrity, organized scepticism, disinterestedness, impersonality.*"

corporate research strategy, university–industry collaboration, and the design of research organizations under uncertainty. For universities and public research organizations, the results underscore the importance of organizational design choices that align with what scientific talent values, particularly during periods of rapid technological change. More broadly, the study suggests that sustainable innovation systems are built not only through investment levels, but through institutional arrangements that enable differentiation and complementarity across organizations. Recognizing and cultivating these complementarities can allow organizations to access scarce expertise, share risks associated with exploratory research, and support innovation without relying solely on pecuniary incentives.

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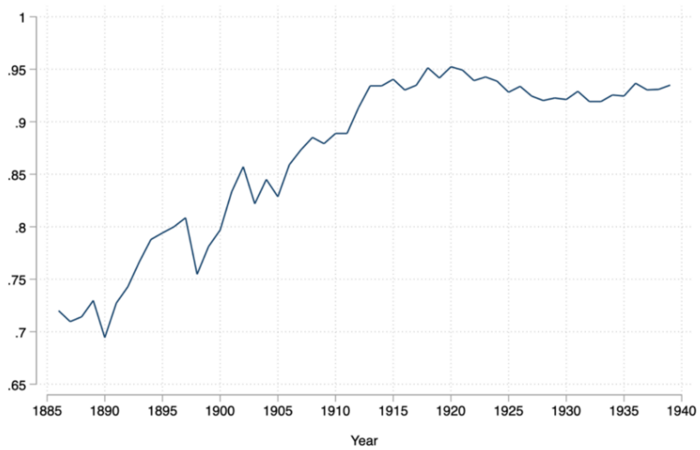
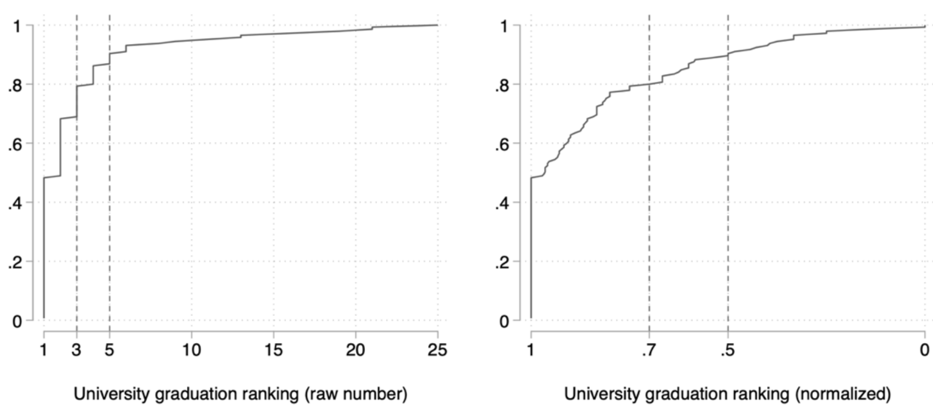
Figures and Tables

Figure 1. Share of Graduates from Science and Engineering Departments of Imperial Universities in Engineering Faculty in Tokyo Imperial University



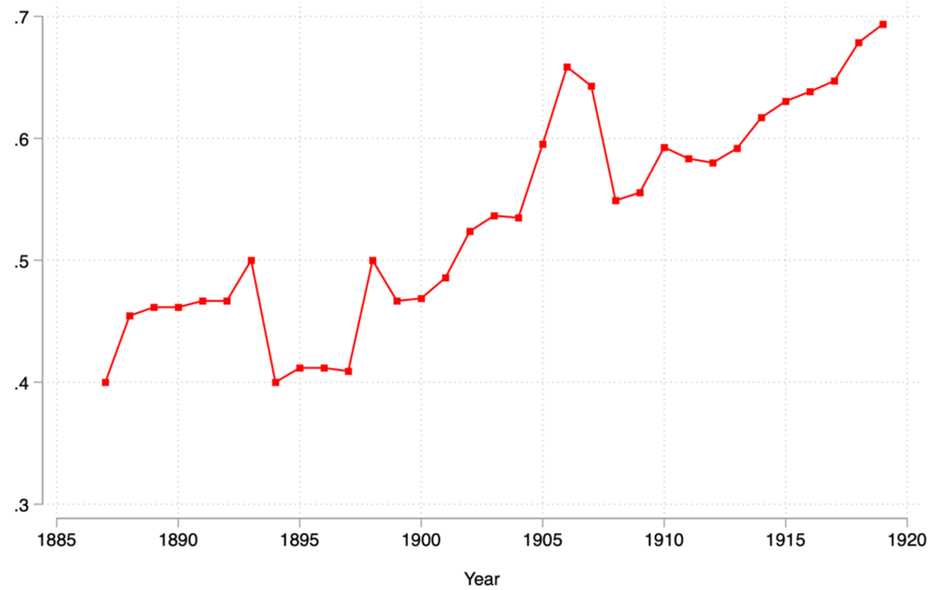
Note: The figure presents the number of graduates from science and engineering departments of Imperial Universities among the engineering faculty members of Tokyo Imperial University in each year, divided by the total number of engineering faculty members of Tokyo Imperial University in that year. Our calculations based on *Tokyo Teikoku Daigaku Ichiran*, 1886-1939.

Figure 2. Empirical Cumulative Distribution of University Graduation Ranking Among Core Engineering Faculty in Tokyo Imperial University



Note: The figures present the empirical cumulative distribution of university graduation ranking among core engineering faculty members of Tokyo Imperial University. The left panel uses the raw numbers of the university graduation ranking as the horizontal axis. The right panel uses the normalized university graduation ranking as the horizontal axis. The normalized university graduation rankings $(Norm\_Rank_i)$ are calculated as follows: $Norm\_Rank_i = (N_i - R_i)/(N_i - 1)$, where R_i is the raw number of the university graduation ranking of graduate i and N_i is the number of graduates in the cohort-division that graduate i belonged to.

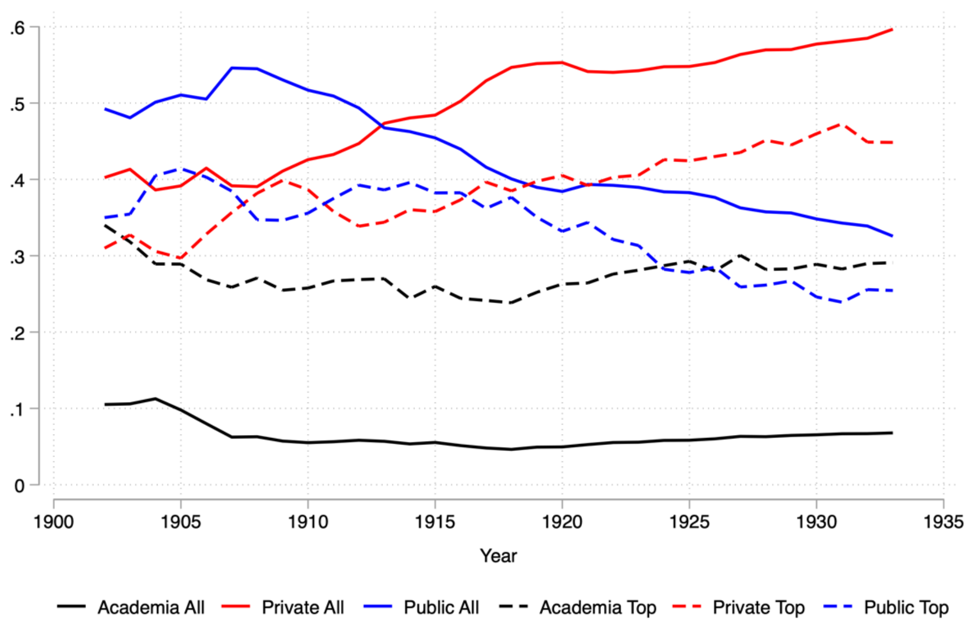
Figure 3. Share of Top-Ranked Graduates Among Core Engineering Faculty in Tokyo Imperial University, 1887-1919



Note: The figure shows the share of top-ranked graduates among core engineering faculty in Tokyo Imperial University by year. The shares are depicted in this figure until 1919 as we do not have any new cohorts added after 1918.

Figure 4.

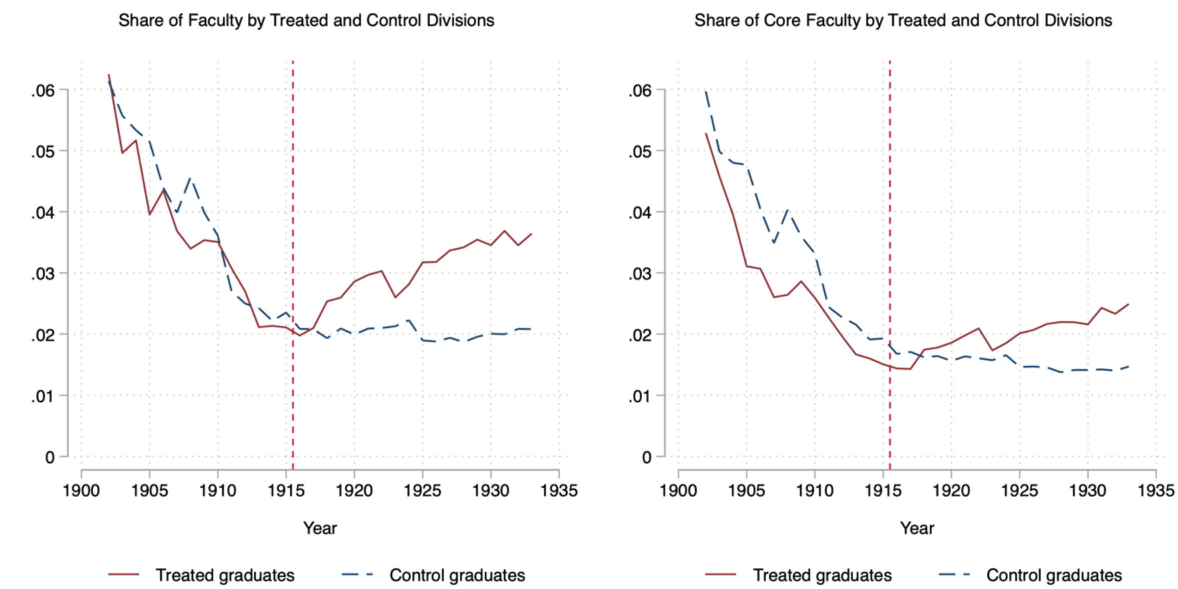
Sectoral Allocation of Tokyo Imperial University College of Engineering Graduates



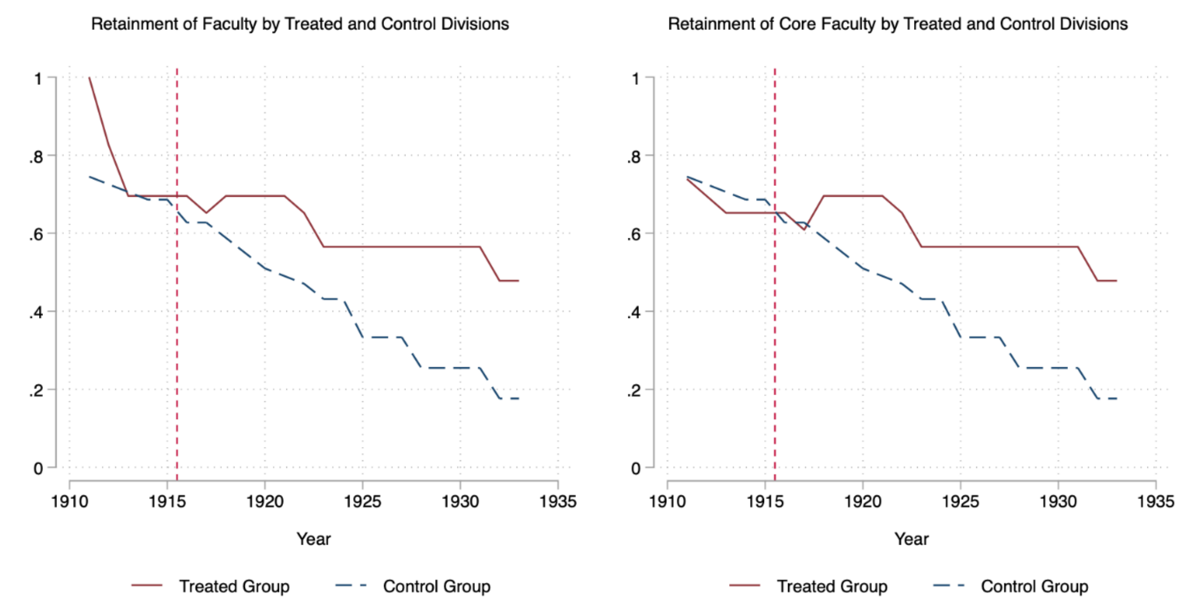
Note: The figure shows the time trend in the shares of all and top-ranked graduates employed in private and public sector and in academia from 1902-1933, the period over which we conduct structural estimation in the main text.

Figure 5. Institute of Aeronautics Effect: Time Trends in the Shares and Retainment of Faculty Between Treated and Control Divisions

Panel A



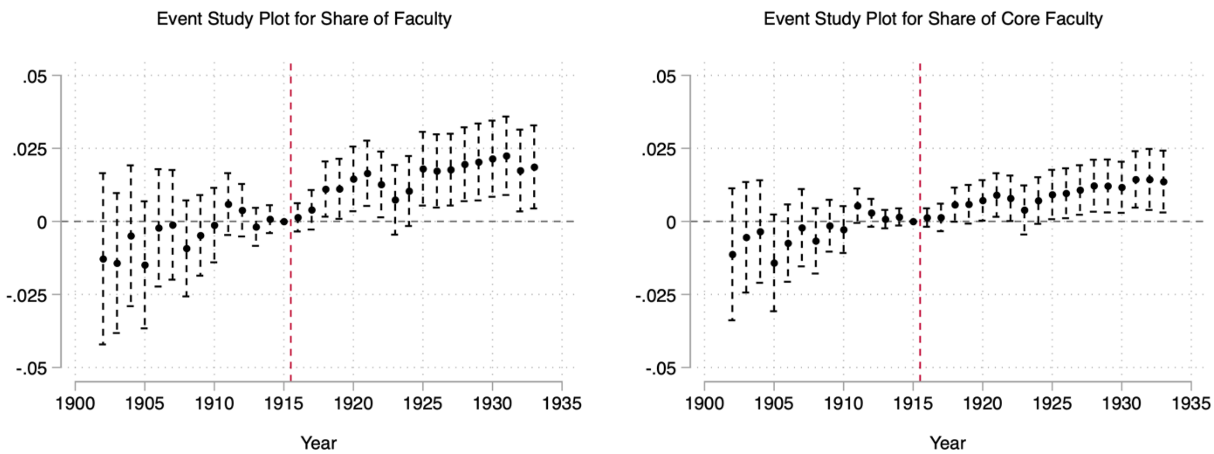
Panel B



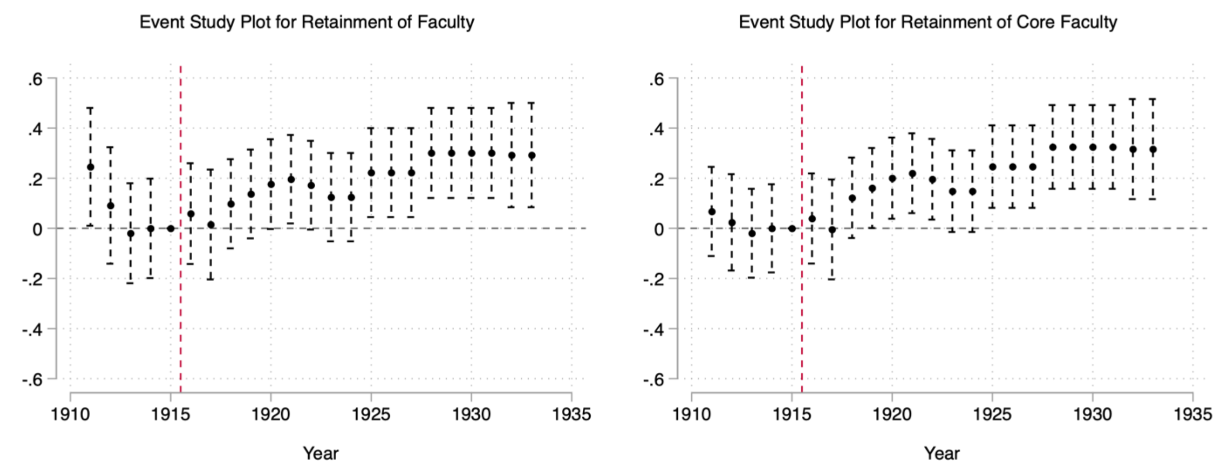
Note: Panel A in the figure shows the time trends in the share of Tokyo Imperial University faculty among all graduates between treated (Naval Architecture and Mechanical Engineering) divisions and other control divisions, while Panel B shows the time trends in the retainment rate of faculty members who had joined Tokyo Imperial University by 1910 between treated and control divisions. The red solid lines represent the treated divisions, while the blue dashed lines represent the control divisions. For both Panel A and B, the left graphs show the trend for all faculty, while the right graphs show the trend for core faculty.

Figure 6. Institute of Aeronautics Effect: Event Study Plots

Panel A

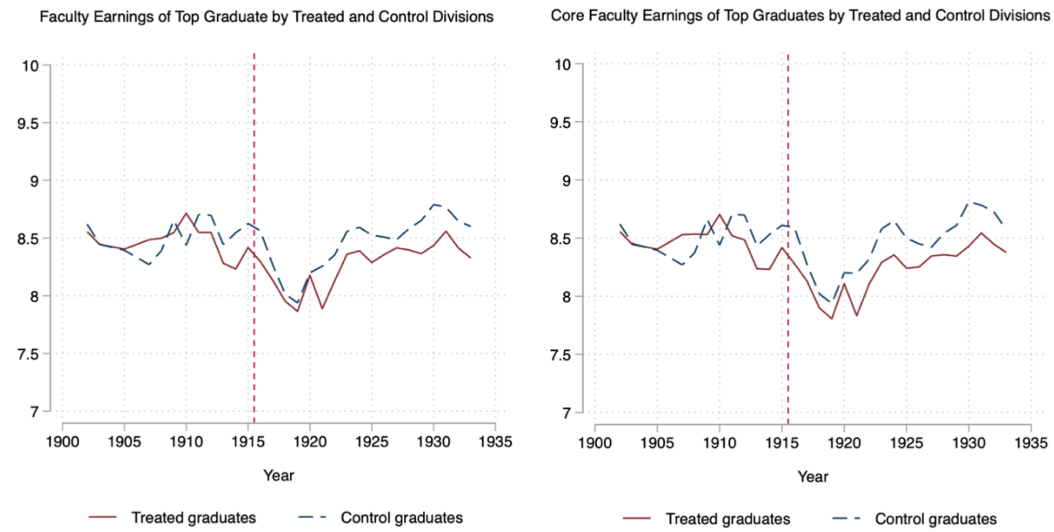


Panel B



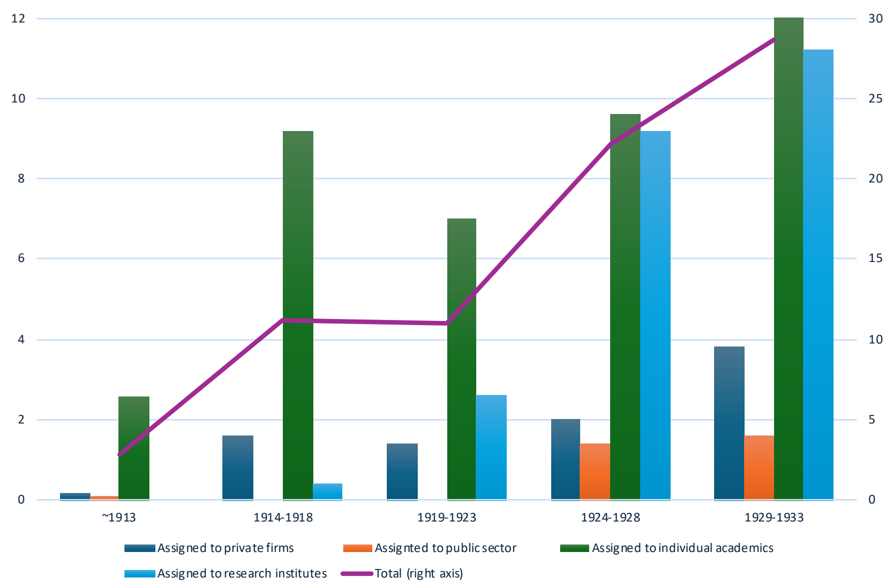
Note: Panel A in the figure shows the event study plots for the share of Tokyo Imperial University faculty among all graduates between treated (Naval Architecture and Mechanical Engineering) divisions and other control divisions, while Panel B shows the event study plots for the retainment rate of faculty members who had already joined Tokyo Imperial University by 1910 between treated and control divisions. For both Panel A and B, the left graphs show the results for all faculty, while the right graphs show the results for the core faculty. Standard errors are clustered at the individual level.

Figure 7. Institute of Aeronautics Effect: Earnings Trends Between Treated and Control Divisions



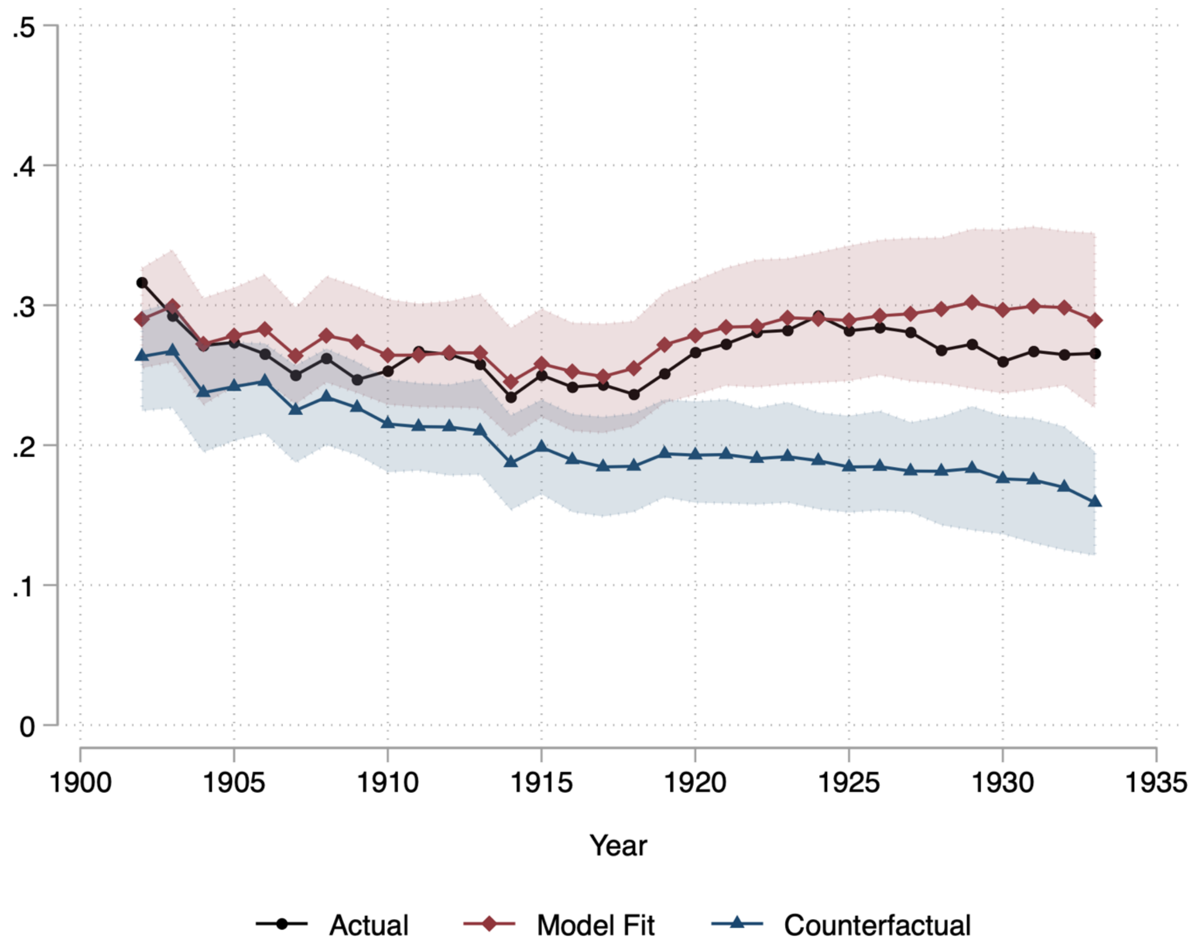
Note: The figure shows the time trends in logged earnings of Tokyo Imperial University faculty between treated (Naval Architecture and Mechanical Engineering) divisions and other control divisions. The red solid lines represent the treated divisions, while the blue dashed lines represent the control divisions. The left panel shows the earnings trend for all faculty, while the right panel shows the earnings trend for core faculty.

Figure 8. Time Trends in Patents by Engineering Faculty and Their Assignments



Note: The line (measured along the right axis) depicts the average number of patents per year by Imperial University engineering faculty for five time periods: all years until 1913, 1914-1918, 1919-1923, 1924-1928, and 1929-1933. The bars (measured along the left axis) show the breakdown of this total into (a) number of patents assigned only to individual academics (green bars), (b) the number of patents assigned or co-assigned to private firms or co-inventors working in private firms (blue bars), (c) the number of patents assigned or co-assigned to public-sector entities or co-inventors working in such entities (orange bars), and (d) the number of patents assigned to affiliated research institutes (including not-for-profit *Riken* and not-for-profit Aoyagi Institute) for the same time periods.

Figure 9. Share of Top Graduates in Academia by Year: Model Fit and Counterfactual



Note: The figure depicts the actual, simulated (with estimated parameters), and counterfactual simulated (with no non-pecuniary payoffs in utility) shares of top graduates in academia by year. The black line with circles represents the actual shares in the data, the red line with diamonds represents the average of the simulated shares with estimated parameters, and the blue line with triangles represents the average of the counterfactual shares where all the coefficients in the non-pecuniary parameters are set to zero. For the model fit and counterfactual simulations, we run 100 simulations for each individual, and the shaded areas represent the 95% interquartile range across those simulations.

Table 1. Reduced-Form Income Regressions for Top-Ranked Engineering Graduates

Dependent Variable: Logged real income	
Imperial University faculty	7.247***
	[0.109]
Employed in private sector	6.562***
	[0.202]
Employed in public sector or military	6.988***
	[0.074]
Years after graduation X Imperial University faculty	0.077***
	[0.012]
Years after graduation X Employed in private sector	0.110***
	[0.024]
Years after graduation X Employed in public sector or military	0.098***
	[0.011]
Years after graduation squared X Imperial University faculty	-0.001***
	[0.000]
Years after graduation squared X Employed in private sector	-0.001**
	[0.001]
Years after graduation squared X Employed in public sector or military	-0.002***
	[0.000]
Time X Imperial University faculty	-0.002
	[0.004]
Time X Employed in private sector	0.024***
	[0.006]
Time X Employed in public sector or military	-0.000
	[0.003]
Observations	3,187
R-squared	0.385

Note: The table shows the coefficient estimates from "Mincer" earning estimation. Estimation method: OLS. Robust standard errors are clustered at the individual level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 2. Patent Subclasses Entropy by Sectors

	(1) All patenting entities	(2) Patenting entities with industry limited to diversified firms	(3) Patenting entities with the number of patent subclasses above 90th percentile	(4) Patent. entities w/# of patent subclasses above 90th percentile & industry limited to diversified firms
Academia (incl. *Riken*)	0.881***	0.443**	0.487***	0.319*
	(0.154)	(0.203)	(0.140)	(0.173)
Public sector	0.014	-0.439***	0.109	-0.076
	(0.084)	(0.142)	(0.132)	(0.171)
Constant	0.602***	1.046***	2.136***	2.300***
	(0.041)	(0.113)	(0.063)	(0.107)
Graduation divisions FE	Included	Included	Included	Included
Observations	525	217	75	48
R-squared	0.099	0.190	0.215	0.174

Note: "Diversified firms" are defined as those whose product portfolio included at least three two-digit SIC codes.

Table 3. Estimates of Non-pecuniary Utility Components (Relative to Private Sector)

	Specification				
	(1)	(2)	(3)	(4)	(5)
Academia (Imperial University):					
Cohort trend (×100)	0.117 [0.028]	0.079 [0.025]	0.091 [0.038]	0.076 [0.038]	0.051 [0.033]
Institute of Aeronautics (×100)		1.527 [0.947]			1.649 [0.990]
Honor student (×100)			1.811 [1.220]		1.076 [0.982]
Top after second year (×100)				1.306 [1.088]	0.533 [0.977]
Public/Military:					
Cohort trend (×100)	0.004 [0.027]	0.005 [0.023]	0.025 [0.029]	0.048 [0.029]	0.044 [0.026]
Honor student (×100)			-0.732 [1.073]		-0.044 [0.809]
Top after second year (×100)				-1.426 [0.837]	-1.222 [0.833]
Observations	3,107	3,107	3,107	3,107	3,107
Number of graduates	258	258	258	258	258

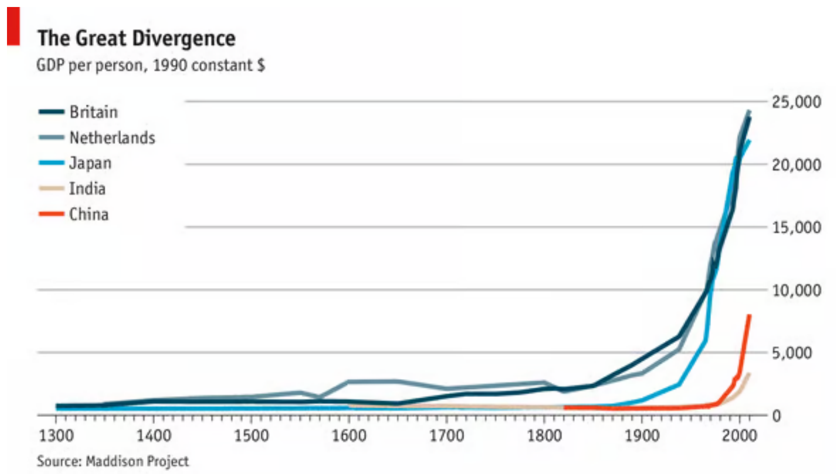
Note: The table shows the coefficient estimates on non-pecuniary utility components (indirect payoffs) from the structural estimation. Each specification includes different set of explanatory variables in the utility function. Specification (1) only includes the cohort trend in the set of individual-specific characteristics; specification (2) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate from Naval Architecture or Mechanical Engineering divisions worked in Imperial University after the establishment of the Institute of Aeronautics; specification (3) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate was also an honor student; (4) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate was also a top student after the second year; and specification (5) includes all of the above variables. The reported estimates are multiplied by 100 if necessary. The standard errors in parentheses are calculated by the parametric bootstrap procedure described in Appendix D.3.

On-Line Appendix to:

If We Build It, We Will Come: Institution Development in Academia and the Evolution of Career Choices by Top Talent During Japan's Industrialization

A. Figures and Tables Cited in the Main Text

Figure A1.



Source: London (2013).

Figure A2. Number of Graduates from Tokyo Imperial University College of Engineering

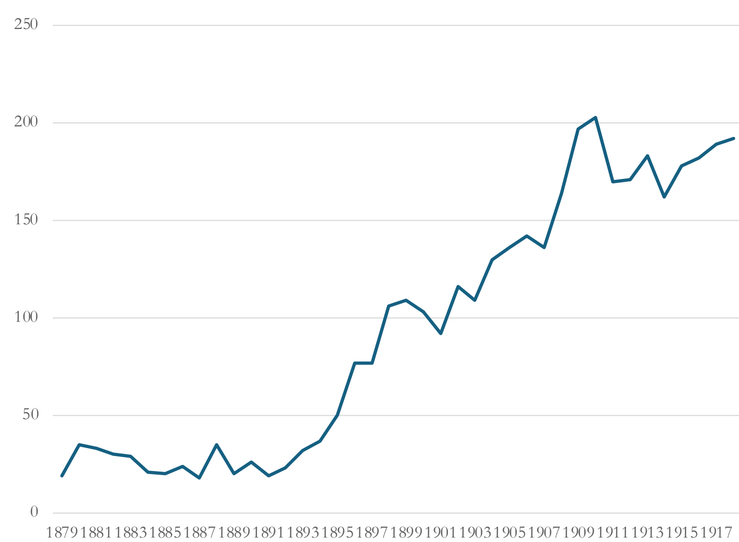
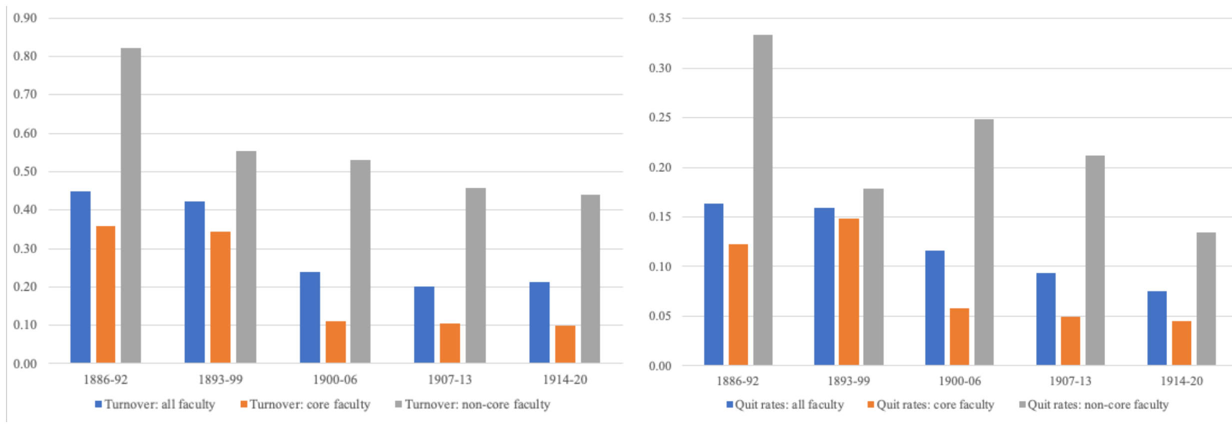


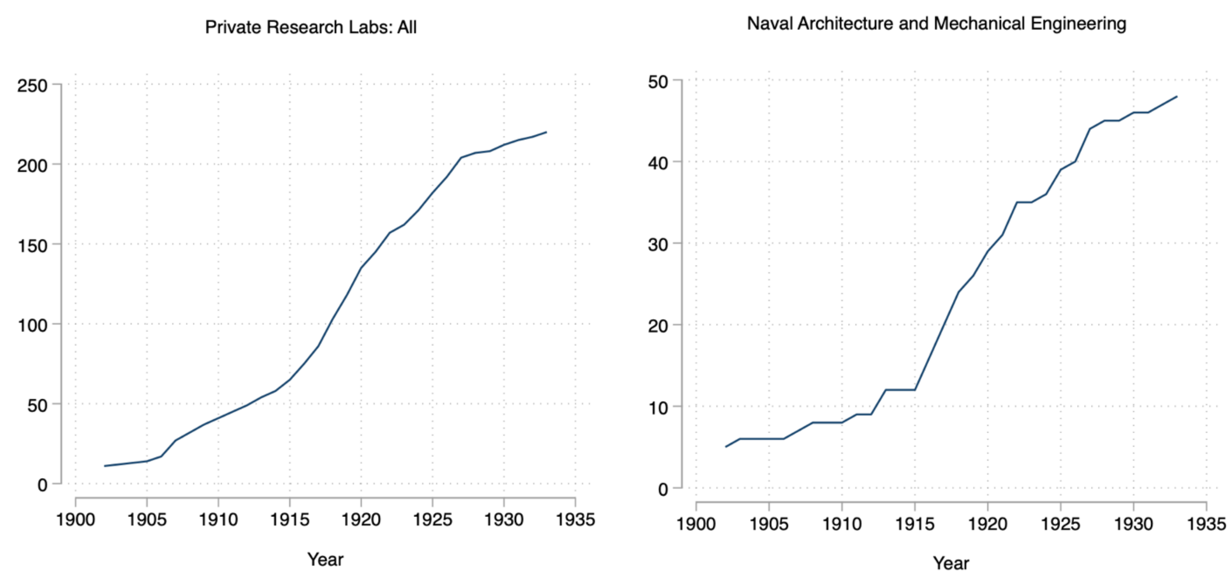
Figure A3. Turnover and Quit Rates Among Engineering Faculty

Panel A. Turnover Rates **Panel B. Quit Rates**



Note: Turnover rate = (# hires + # quits)/ (total # of faculty) in a given year. Quit rate = # quits / total # of faculty in a given year. The bars represent averages over five seven-year periods. Our calculations based on *Tokyo Teikoku Daigaku Ichiran*, 1886-1939.

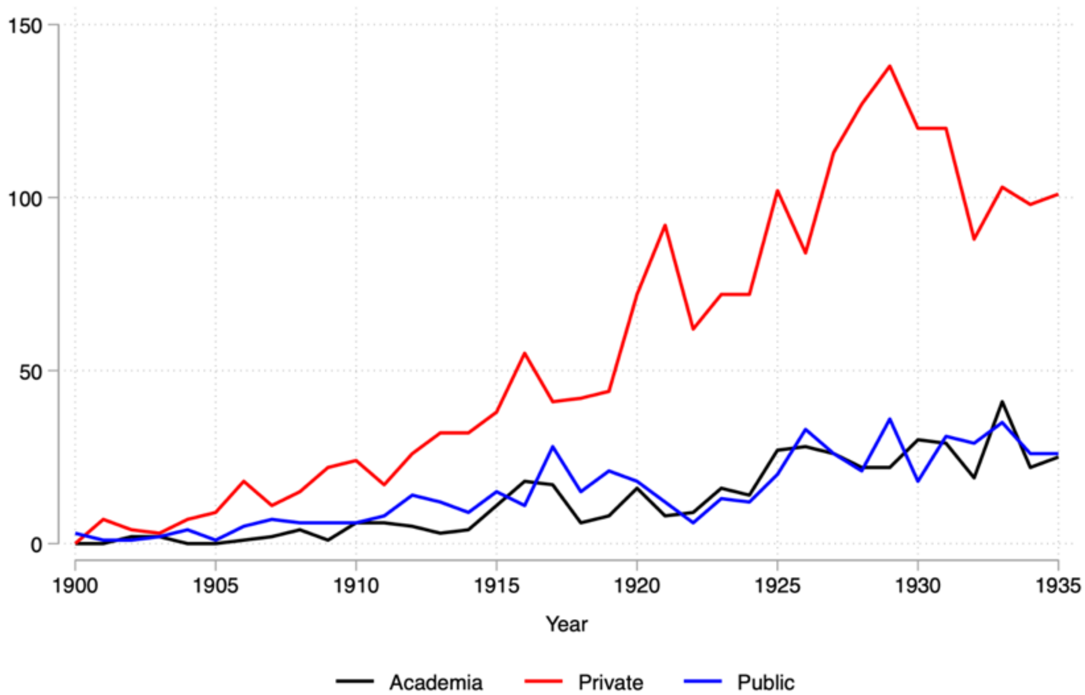
Figure A4. Time Trend in the Cumulative Number of Research Institutes and Labs in Industry



Note: The left panel shows the cumulative number of all private research institutes and labs in each year. The right panel shows the cumulative number of private research institutes and labs in aeronautics-related industries (industrial and commercial machinery, including engines, generators, etc., and transportation equipment, including shipbuilding, aircraft, etc.) in each year.

Figure A5. Number of Patents per Year by Sector of Employment

Panel A. Average Number of Patents per Year



Panel B. Number of Patents per Graduate per Year

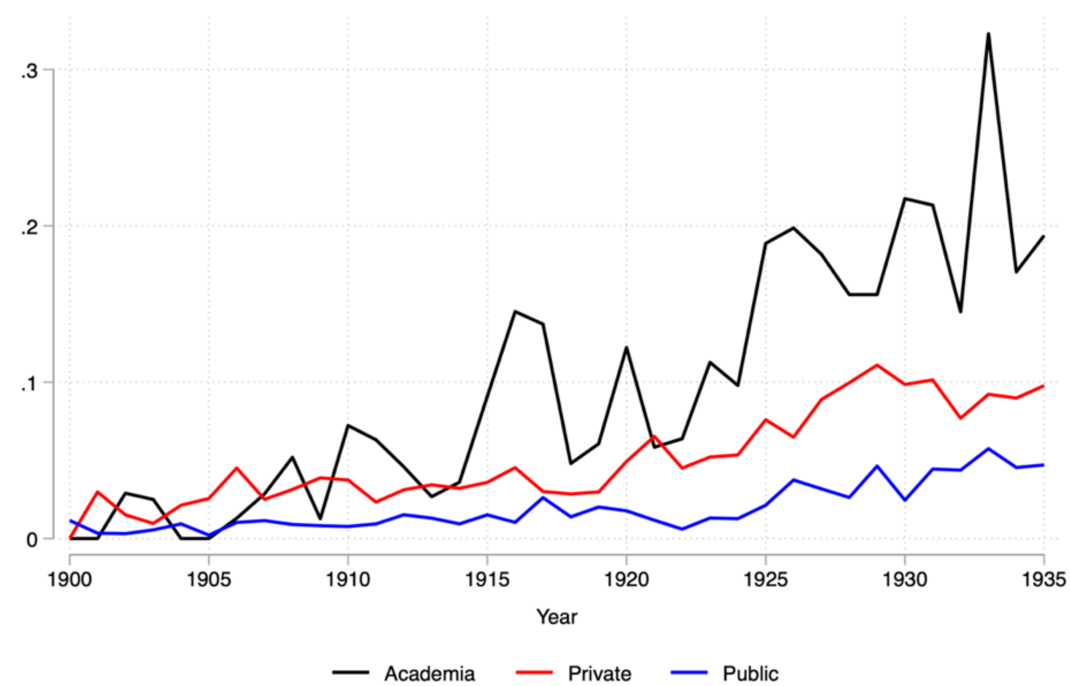
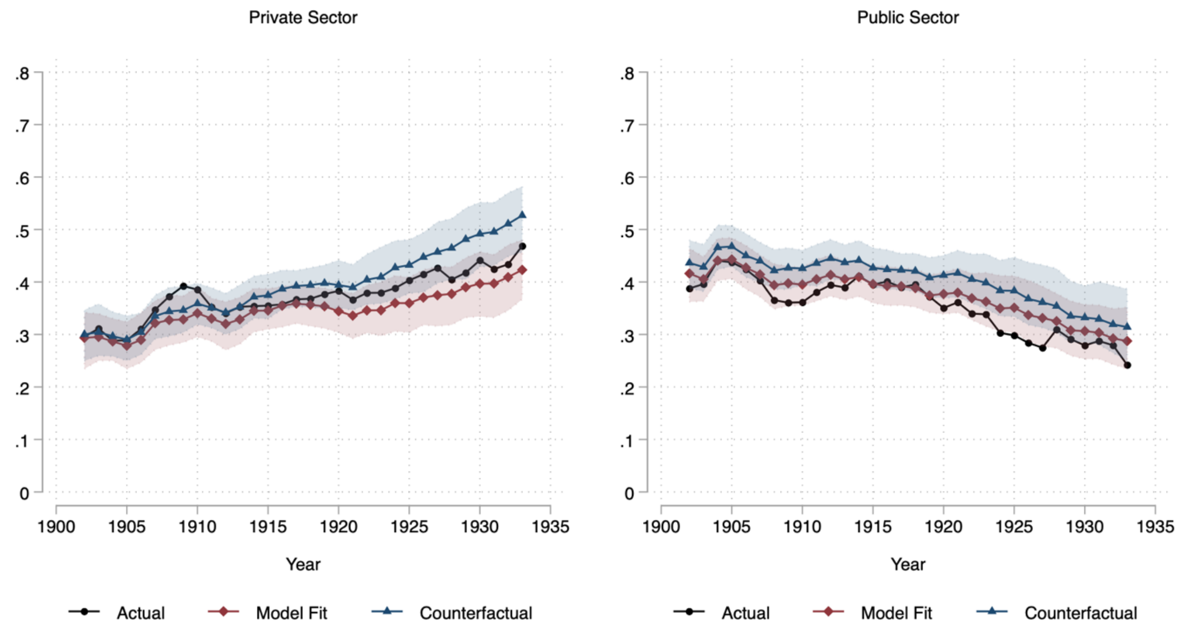


Figure A6. Share of Top Graduates in Private and Public Sectors by Year: Model Fit and Counterfactual



Note: The figure depicts the actual, simulated (with estimated parameters), and counterfactual simulated (with no non-pecuniary payoffs in utility) shares of top graduates in private and public sectors by year. The black line with circles represents the actual shares in the data, the red line with diamonds represents the average of the simulated shares with estimated parameters, and the blue line with triangles represents the average of the counterfactual shares where all the coefficients in the non-pecuniary parameters are set to zero. For the model fit and counterfactual simulations, we run 100 simulations for each individual, and the shaded areas represent the 95% interquartile range across those simulations.

Table A1. Tokyo Imperial University Salary Scales

Panel A (yen per annum)

	Year					
Grade (full professors)	1893	1897	1907	1910	1919	1920
1	1200	1600	2000	2500	3000	4500
2	1000	1400	1800	2200	2700	4100
3	1000	1200	1600	2000	2500	3800
4	900	1100	1400	1700	2200	3400
5	800	1000	1200	1500	2000	3100
6		900	1000	1300	1700	2700
7		800	900	1200	1500	2400
8			800	1100	1200	2000
9				1000	1100	1800
10					1000	1600
11						1400
12						1200

	Year					
Grade (asst. professors)	1893	1897	1907	1910	1919	1920
1	600	800	1000	1200	2000	3100
2	500	700	900	1100	1700	2800
3	400	600	800	1000	1500	2600
4	300	500	700	850	1200	2400
5		400	600	750	1100	2200
6		300	500	600	850	2000
7			400	500	750	1800
8			300	400	600	1600
9					500	1400
10						1300
11						1200
12						1100

Source: *Tokyo Daigaku Hyakunenshi* (1977, Vol. 8).

Table A1. Tokyo Imperial University Salary Scales (Continued)

Panel B (yen per annum, deflated by the consumer price index, 1897 = 1)

	Year					
Grade (full professors)	1893	1897	1907	1910	1919	1920
1	1664	1600	1363.5	1831.6	919.4	1318.8
2	1386	1400	1227.1	1611.8	827.5	1201.5
3	1386	1200	1090.8	1465.3	766.2	1113.6
4	1248	1100	954.4	1245.5	674.2	996.4
5	1109	1000	818.1	1099.0	612.9	908.5
6		900	681.7	952.4	521.0	791.3
7		800	613.6	879.2	459.7	703.3
8			545.4	805.9	367.8	586.1
9				732.6	337.1	527.5
10					306.5	468.9
11						410.3
12						351.7

	Year					
Grade (asst. professors)	1893	1897	1907	1910	1919	1920
1	832	800	681.7	879.2	612.9	908.5
2	693	700	613.6	805.9	521.0	820.6
3	555	600	545.4	732.6	459.7	761.9
4	416	500	477.2	622.7	367.8	703.3
5		400	409.0	549.5	337.1	644.7
6		300	340.9	439.6	260.5	586.1
7			272.7	366.3	229.8	527.5
8			204.5	293.1	183.9	468.9
9					153.2	410.3
10						381.0
11						351.7
12						322.4

Source: *Tokyo Daigaku Hyakunenshi* (1977, Vol. 8). Consumer price deflator from Ohkawa K. et al. (1967), *Choki Keizai Tokei* ((Estimates of Long-Term Economic Statistics of Japan Since 1868), Vol. 8, *Bukka* (Prices), Toyo Keizai Shimposha, Tokyo, p. 135.

Table A2. Number and Fraction of Graduates Who Became Engineering Faculty

Panel A. Number and fraction of Tokyo Imperial University engineering graduates until the 1918 graduation cohort who became engineering faculty

	Division Graduated From									
	Civil Engineering	Mechanical Engineering	Naval Architecture	Electric Engineering	Architecture	Applied Chemistry	Metal and Mining	Ordnance	Explosives	Total
Never Engineering Faculty	792 (95.65)	759 (92.67)	322 (90.20)	526 (94.95)	234 (92.13)	317 (89.04)	491 (93.08)	69 (84.15)	14 (70.00)	3,524 (92.91)
Engineering Faculty	36 (4.35)	60 (7.33)	35 (9.80)	28 (5.005	20 (7.87)	39 (10.96)	32 (6.12)	13 (15.85)	6 (30.00)	269 (7.09)
Total	828	819	357	554	254	356	523	82	20	3,793

Panel B. Number and fraction of top graduates in their divisions and cohorts among Tokyo Imperial University engineering graduates who became engineering faculty

	Division Graduated From									
	Civil Engineering	Mechanical Engineering	Naval Architecture	Electric Engineering	Architecture	Applied Chemistry	Metal and Mining	Ordnance	Explosives	Total
Never Engineering Faculty	32 (68.09)	40 (68.97)	17 (53.12)	30 (76.92)	22 (73.33)	22 (62.86)	39 (70.91)	10 (62.50)	3 (60.00)	215 (67.82)
Engineering Faculty	15 (31.91)	18 (31.03)	15 (46.08)	9 (23.08)	8 (26.67)	13 (37.14)	16 (29.09)	6 (37.50)	2 (40.00)	102 (32.18)
Total	47	58	32	39	30	35	55	16	5	317

Panel C. Number and fraction of inventors among Tokyo Imperial University engineering graduates who became engineering faculty

	Division Graduated From									
	Civil Engineering	Mechanical Engineering	Naval Architecture	Electric Engineering	Architecture	Applied Chemistry	Metal and Mining	Ordnance	Explosives	Total
Never Engineering Faculty	61 (91.04)	177 (85.51)	37 (82.22)	145 (90.62)	18 (85.71)	149 (84.66)	78 (82.98)	14 (82.35)	7 (58.33)	686 (85.86)
Engineering Faculty	6 (8.96)	30 (14.49)	8 (17.78)	15 (9.38)	3 (14.29)	27 (15.34)	16 (17.02)	3 (17.65)	5 (41.67)	113 (14.14)
Total	67	207	45	160	21	176	94	17	12	799

Panel D. Number and fraction of global inventors among Tokyo Imperial University engineering graduates who became engineering faculty

	Division Graduated From									
	Civil Engineering	Mechanical Engineering	Naval Architecture	Electric Engineering	Architecture	Applied Chemistry	Metal and Mining	Ordnance	Explosives	Total
Never Engineering Faculty	6 (100.00)	27 (79.41)	5 (62.50)	21 (75.00)	2 (100.00)	21 (84.00)	9 (75.00)	0 (-)	0 (-)	91 (77.78)
Engineering Faculty	0 (-)	7 (20.59)	3 (37.50)	7 (25.00)	0 (-)	4 (16.00)	3 (25.00)	2 (100.00)	0 (-)	26 (22.22)
Total	6	34	8	28	2	25	12	2	0	117

Note: Panel A shows the number and fraction (in parentheses) of graduates from Tokyo Imperial University College of Engineering who did or did not become faculty in their alma mater (the same College of Engineering) at some point between 1886-1939. Panel B shows the number and fraction (in parentheses) of graduates who were ranked at the top of their division-cohorts (conditional on there being more than one graduate) at the time of graduation among graduates from Tokyo Imperial University College of Engineering who did or did not become faculty in their alma mater at some point between 1886-1939. Panel C shows the number and fraction (in parentheses) of inventors (individuals with at least one patent in the sample) among graduates from Tokyo Imperial University College of Engineering who did or did not become faculty in their alma mater at some point between 1886-1939. Panel D shows the number and fraction (in parentheses) of global inventors (individuals with at least one U.S., British or other foreign patent in the sample) among graduates from Tokyo Imperial University College of Engineering who did or did not become faculty in their alma mater at some point between 1886-1939. Faculty divisions are defined as divisions in which graduates were hired as faculty for the first time.

Table A3. Structural Estimation Parameters (1)

Earning Parameters

	Specification				
	(1)	(2)	(3)	(4)	(5)
Academia:					
Intercept	7.608 [0.024]	7.560 [0.022]	7.596 [0.026]	7.566 [0.029]	7.592 [0.027]
Year after graduation	0.080 [0.002]	0.076 [0.002]	0.082 [0.002]	0.083 [0.002]	0.084 [0.002]
Year after graduation^2 (×100)	-0.110 [0.004]	-0.105 [0.004]	-0.116 [0.005]	-0.120 [0.006]	-0.121 [0.006]
Year trend (×100)	-0.221 [0.043]	-0.046 [0.038]	-0.194 [0.055]	-0.129 [0.065]	-0.239 [0.063]
Error variance	0.354 [0.005]	0.356 [0.005]	0.353 [0.005]	0.353 [0.005]	0.353 [0.005]
Private:					
Intercept	6.056 [0.031]	6.029 [0.026]	5.946 [0.030]	5.980 [0.036]	5.997 [0.033]
Year after graduation	0.101 [0.002]	0.096 [0.002]	0.099 [0.002]	0.094 [0.003]	0.096 [0.003]
Year after graduation^2 (×100)	-0.122 [0.004]	-0.111 [0.004]	-0.119 [0.005]	-0.108 [0.006]	-0.110 [0.006]
Year trend (×100)	2.757 [0.052]	3.006 [0.045]	3.156 [0.058]	3.157 [0.076]	3.071 [0.071]
Error variance	0.591 [0.007]	0.591 [0.007]	0.590 [0.008]	0.590 [0.009]	0.590 [0.008]
Public/Military:					
Intercept	7.078 [0.020]	7.058 [0.018]	7.103 [0.021]	7.147 [0.024]	7.135 [0.023]
Year after graduation	0.102 [0.002]	0.112 [0.002]	0.109 [0.002]	0.109 [0.002]	0.107 [0.002]
Year after graduation^2 (×100)	-0.158 [0.004]	-0.183 [0.004]	-0.173 [0.005]	-0.170 [0.005]	-0.168 [0.005]
Year trend (×100)	-0.092 [0.046]	-0.270 [0.042]	-0.334 [0.050]	-0.461 [0.056]	-0.403 [0.055]
Error variance	0.338 [0.004]	0.337 [0.004]	0.337 [0.005]	0.337 [0.005]	0.337 [0.004]

Note: The table shows the coefficient estimates on earning parameters from the structural estimation. Each specification includes different set of explanatory variables in the utility function. Specification (1) only includes the cohort trend in the set of individual-specific characteristics; specification (2) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate from Naval Architecture or Mechanical Engineering divisions worked in Imperial University after the establishment of the Institute of Aeronautics; specification (3) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate was also an honor student; (4) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate was also a top student after the second year; and specification (5) includes all of the above variables. The reported estimates are multiplied by 100 if necessary. The standard errors in parentheses are calculated by the parametric bootstrap procedure described in Appendix D.3.

Table A4. Structural Estimation Parameters (2)

Switching Cost Parameters

	Specification				
	(1)	(2)	(3)	(4)	(5)
Academia:					
Intercept	0.672 [0.042]	0.351 [0.041]	0.690 [0.052]	0.561 [0.054]	0.407 [0.051]
Year after graduation	0.036 [0.002]	0.043 [0.002]	0.036 [0.002]	0.037 [0.003]	0.038 [0.003]
Year after graduation^2 (×100)	-0.112 [0.006]	-0.133 [0.005]	-0.113 [0.007]	-0.115 [0.009]	-0.117 [0.009]
Private:					
Intercept	0.936 [0.039]	0.685 [0.041]	0.966 [0.050]	0.840 [0.062]	0.695 [0.055]
Year after graduation	-0.040 [0.002]	-0.042 [0.002]	-0.045 [0.002]	-0.041 [0.003]	-0.042 [0.003]
Year after graduation^2 (×100)	0.082 [0.005]	0.085 [0.005]	0.094 [0.006]	0.084 [0.008]	0.084 [0.007]
Public/Military:					
Intercept	-0.004 [0.049]	-0.261 [0.043]	-0.009 [0.056]	-0.080 [0.064]	-0.226 [0.068]
Year after graduation	0.078 [0.003]	0.076 [0.002]	0.078 [0.003]	0.075 [0.003]	0.074 [0.003]
Year after graduation^2 (×100)	-0.175 [0.006]	-0.172 [0.005]	-0.174 [0.007]	-0.170 [0.008]	-0.168 [0.008]

Preference Shock Parameters

	Specification				
	(1)	(2)	(3)	(4)	(5)
Preference variance	0.413 [0.011]	0.311 [0.008]	0.414 [0.013]	0.369 [0.014]	0.318 [0.011]

Note: The table shows the coefficient estimates on switching cost and preference shock from the structural estimation. Each specification includes different set of explanatory variables in the utility function. Specification (1) only includes the cohort trend in the set of individual-specific characteristics; specification (2) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate from Naval Architecture or Mechanical Engineering divisions worked in Imperial University after the establishment of the Institute of Aeronautics; specification (3) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate was also an honor student; (4) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate was also a top student after the second year; and specification (5) includes all of the above variables. The reported estimates are multiplied by 100 if necessary. The standard errors in parentheses are calculated by the parametric bootstrap procedure described in Appendix D.3.

Table A5. Structural Estimation Parameters (3)

Type Distribution Parameters

	Specification				
	(1)	(2)	(3)	(4)	(5)
Type 1	0.326 [0.029]	0.340 [0.030]	0.303 [0.030]	0.319 [0.030]	0.287 [0.032]
Type 2	0.039 [0.012]	0.040 [0.012]	0.039 [0.013]	0.040 [0.016]	0.038 [0.017]
Type 3	0.251 [0.025]	0.256 [0.025]	0.257 [0.024]	0.261 [0.030]	0.266 [0.032]
Type 4	0.384 [0.030]	0.364 [0.031]	0.401 [0.031]	0.380 [0.031]	0.409 [0.036]

Preference Heterogeneity Parameters

	Specification				
	(1)	(2)	(3)	(4)	(5)
Academia:					
Type 1	0.034 [0.009]	0.020 [0.007]	0.037 [0.010]	0.032 [0.010]	0.027 [0.010]
Type 2	0.013 [0.017]	0.014 [0.014]	0.009 [0.023]	0.009 [0.020]	0.009 [0.020]
Type 3	-0.028 [0.009]	-0.019 [0.009]	-0.026 [0.011]	-0.021 [0.010]	-0.019 [0.009]
Type 4	-0.019 [0.010]	-0.015 [0.008]	-0.021 [0.012]	-0.021 [0.011]	-0.016 [0.011]
Public/Military:					
Type 1	-0.003 [0.009]	-0.010 [0.007]	-0.003 [0.010]	-0.006 [0.010]	-0.004 [0.009]
Type 2	0.055 [0.017]	0.044 [0.011]	0.056 [0.018]	0.052 [0.018]	0.046 [0.016]
Type 3	-0.038 [0.010]	-0.028 [0.007]	-0.037 [0.011]	-0.035 [0.010]	-0.030 [0.008]
Type 4	-0.013 [0.009]	-0.006 [0.007]	-0.015 [0.009]	-0.011 [0.009]	-0.012 [0.008]

Note: The table shows the coefficient estimates on type distribution and preference heterogeneity parameters from the structural estimation. Each specification includes different set of explanatory variables in the utility function. Specification (1) only includes the cohort trend in the set of individual-specific characteristics; specification (2) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate from Naval Architecture or Mechanical Engineering divisions worked in Imperial University after the establishment of the Institute of Aeronautics; specification (3) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate was also an honor student; (4) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate was also a top student after the second year; and specification (5) includes all of the above variables. The reported estimates are multiplied by 100 if necessary. The standard errors in parentheses are calculated by the parametric bootstrap procedure described in Appendix D.3.

Table A6. Structural Estimation Parameters (4)

Earning Potential Heterogeneity Parameters

	Specification				
	(1)	(2)	(3)	(4)	(5)
Academia:					
Type 1	-0.609	-0.575	-0.635	-0.638	-0.641
	[0.014]	[0.015]	[0.013]	[0.016]	[0.015]
Type 2	0.971	0.901	1.053	1.070	1.071
	[0.026]	[0.026]	[0.030]	[0.036]	[0.031]
Type 3	-0.005	0.004	-0.033	-0.041	-0.037
	[0.016]	[0.014]	[0.018]	[0.019]	[0.018]
Type 4	-0.358	-0.331	-0.386	-0.391	-0.393
	[0.014]	[0.015]	[0.015]	[0.015]	[0.014]
Private:					
Type 1	-0.720	-0.715	-0.722	-0.726	-0.735
	[0.024]	[0.022]	[0.026]	[0.029]	[0.028]
Type 2	1.006	1.039	1.070	1.069	1.076
	[0.036]	[0.033]	[0.043]	[0.054]	[0.047]
Type 3	0.163	0.144	0.159	0.160	0.159
	[0.017]	[0.019]	[0.019]	[0.023]	[0.021]
Type 4	-0.449	-0.469	-0.507	-0.503	-0.501
	[0.019]	[0.018]	[0.022]	[0.026]	[0.023]
Public/Military:					
Type 1	-0.358	-0.353	-0.366	-0.372	-0.371
	[0.011]	[0.011]	[0.011]	[0.012]	[0.012]
Type 2	0.396	0.375	0.399	0.407	0.406
	[0.019]	[0.018]	[0.020]	[0.021]	[0.022]
Type 3	0.061	0.064	0.058	0.061	0.061
	[0.012]	[0.013]	[0.013]	[0.013]	[0.013]
Type 4	-0.098	-0.086	-0.091	-0.095	-0.096
	[0.010]	[0.009]	[0.011]	[0.011]	[0.012]

Note: The table shows the coefficient estimates on earning potential heterogeneity parameters from the structural estimation. Each specification includes different set of explanatory variables in the utility function. Specification (1) only includes the cohort trend in the set of individual-specific characteristics; specification (2) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate from Naval Architecture or Mechanical Engineering divisions worked in Imperial University after the establishment of the Institute of Aeronautics; specification (3) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate was also an honor student; (4) includes the cohort trend and the dummy equal to one and zero otherwise if the top graduate was also a top student after the second year; and specification (5) includes all of the above variables. The reported estimates are multiplied by 100 if necessary. The standard errors in parentheses are calculated by the parametric bootstrap procedure described in Appendix D.3.

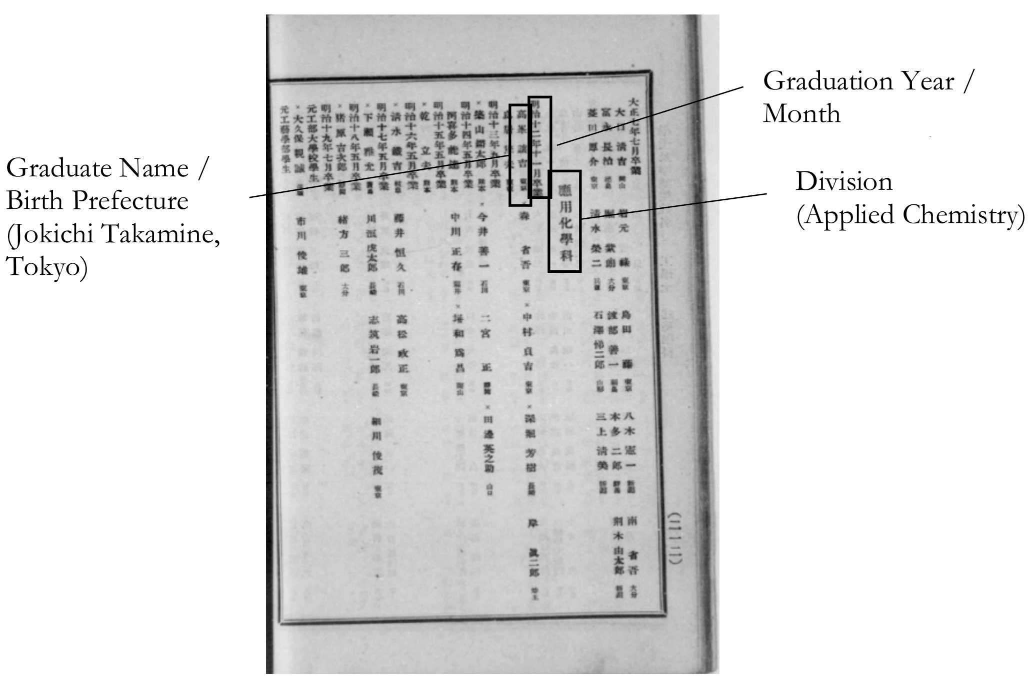
B. Data and the Sample

B.1. Annual Calendars of Imperial Universities (*Ichiran*)

As mentioned in the main text, our first data source is annual Calendars of Imperial Universities (such as *Tokyo Teikoku Daigaku Ichiran*, also called *Tokyo Teikoku Daigaku Yoran* in some years) available in open access from the National Diet Library Digital Collections (https://dl.ndl.go.jp/en/). These calendars contain names, birth prefectures, and divisions of all students during their years at the university as well as graduation years and months after graduation. The calendars also contain information on all faculty, including job titles, degrees, and specialization (including any chairs the faculty held). Importantly, up until 1918, Tokyo Imperial University Calendars listed the students in the order (*Sekiji*, in Japanese) of the average of their test scores in each year, while the graduates were listed in the order of average test scores over all three years of university education, with the score of their graduation diploma added as the fourth component. Thus, the ordering of names is reflective of academic performance relative to peers (in the same division and cohort). As an example, Figure B1 shows that Jokichi Takamine (the discoverer of adrenaline) graduated from the applied chemistry division at the top of the class of six people in 1879.

From these calendars, we digitized the data on all bachelor's degree recipients in engineering from Japan's first (Tokyo) Imperial University and its predecessor (Imperial College of Engineering), starting from the first graduation cohort in 1879 and until the 1918 graduation cohort. We also digitized faculty data from the four Imperial Universities in our sample until 1939 to supplement the data from the alumni lists described next.

Figure B1. A sample page of graduates lists in Tokyo Imperial University *Ichiran*

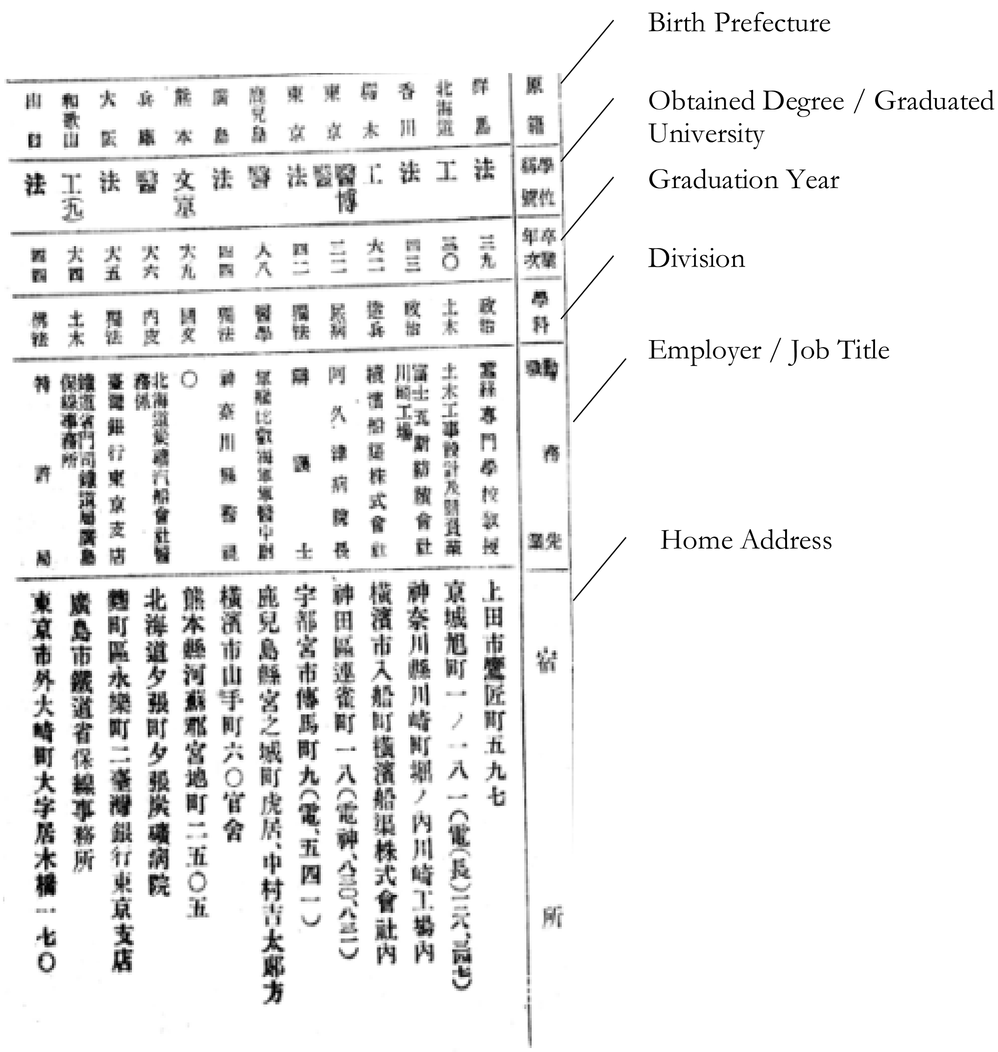


Source: Annual Catalog of Tokyo Imperial University (*Ichiran*) Taisho 7 (1918).

B.2. Annual Alumni Surveys of Imperial Universities' Graduates ("*Gakushikai Kaiin Shimeiroku*")

We hand-matched the data on all engineering graduates from the (Tokyo) Imperial University described in the previous section with *Gakushikai Kaiin Shimeiroku*, the Alumni Surveys of Imperial Universities' Graduates. Images of those surveys for every year from 1890 to 1940 (with two missing years, 1893 and 1894) were provided to us by *Gakushikai* (the Alumni Association), and they contain information about addresses and workplaces for each graduate belonging to the association, updated annually. We digitized information for all the graduates in our sample of engineering graduates who were found in these surveys (more than 90% of the universe of all graduates) to construct longitudinal data on their employers and addresses. Figure B2 shows how the information for each graduate appears in these surveys.

Figure B2 A sample page from the annual alumni surveys of Imperial Universities' graduates



Source: Annual Alumni Surveys of Imperial Universities' Graduates ("*Gakushikai Kaiin Shimeiroku*") Taisho 9 (1920). The graduate names are not displayed.

While some parts of the afore-mentioned alumni surveys were used in past studies by Japanese historians (Uchida, 1979; Uemura, 2017a,b; Sawai, 2020), we are the first to use *all* the data available on engineering graduates from those surveys. One of the most challenging aspects in creating the full longitudinal database from the alumni surveys was to keep track of name changes that were common in Japan at that time, mostly due to frequent cases of adult adoption.[1] The writing of characters in the names also varies from year to year, which presented another challenge. For Imperial University engineering faculty whose data are used in the current paper we also cross-checked the information from the alumni surveys with Imperial University Calendars and also with Japan's *Who is Who* as described below.

B.3. Top Graduates' Earnings Data Based on *Who is Who in Japan* (*Nihon Shinshiroku*)

Examining how top graduates made their occupational choices and the role played by pecuniary versus non-pecuniary preferences required individual-level earnings data. Such data are not available from the alumni surveys, nor are they systematically available for the universe of all Imperial University graduates from any other source we are aware of. It turned out, however, that *Who is Who in Japan* (*Nihon Shinhiroku*) contains information on income taxes paid by the individuals included in its listings, starting from the volume published in 1902.[2]

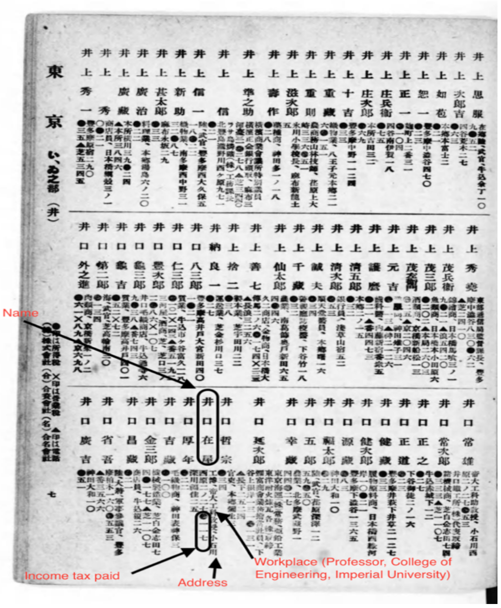
Who is Who in Japan was first published in 1889 by a private company called *Kojunsha* with the aim of creating a list of prominent people across various professions, based on information about income taxation and some additional criteria (*Nihon Shinshiroku,* Vol. *2,* p. 4). For more than a decade, it included only names, workplaces and addresses, but from the 1902 edition, it started publishing also income (and business) tax data. The coverage areas, which in 1889 included only Tokyo and vicinity were also expanded over time (more on this below). Figure B3 shows the 1919 entry for Inokuty Aria, Professor at the College of Engineering in the Imperial University and a top graduate in our sample.

Using names, addresses, and workplaces in *Who is Who in Japan* we hand-matched top graduates from the College of Engineering who comprise our sample for structural estimation of occupational choice and hand-coded the data on income taxes they paid. The matching process was rather smooth as top graduates from our main panel database turned out to be quite likely to make it to the list in *Who is Who in Japan* (although subject to some caveats discussed in the sample selection issue subsection below), so we were able to match almost 90% (260 out of 301 individuals) in at least one year, giving us 3,293 non-missing income tax observations in years 1902-1933.

[1] It was common in the Edo and Meiji era that people occasionally had multiple names and changed their own names. Although the government enforced laws prohibiting multiple names and renaming in 1873, it relaxed the regulations due to a strong backlash (Yamanushi, 1962). As a result, we observe many cases of changes in both family and given names for the same individuals. For most cases, however, both old and new names were listed for the same individual in separate sections of *Gakushikai Kaiin Shimeiroku* which were used to identify such cases. We also used *Imperial University Calendars*, High-school Registries (*High-school Calendars*), and online sources to track name changes.

[2] We are grateful to Junichi Yamasaki for pointing out this source of data to us.

Figure B3. A sample page from *Who is Who in Japan* (*Nihon Shinshiroku*)



Source: *Nihon Shinshiroku*, Taisho 8 (1919), p. 7, url: https://dl.ndl.go.jp/pid/1704493/1/85

Income tax data needed to be converted into actual earnings. The income tax code changed multiple times during our sample (including emergency wartime tax imposed during the Russo-Japanese war and the transition to the system of excess progressive rates from the system of simple progressive rates in 1913). Those changes are documented in annual reports by Japan's Tax Bureau (*Shuzeikyoku Tokei Nemposho*). We use the tax schedules reported in those reports for each year from 1902-1933 to back-calculate the earnings that gave rise to income taxes reported in *Who is Who in Japan* (details are available upon request).

The median annual real income (nominal income deflated by the consumer price index) among top graduates used for structural estimation in our paper is 3,784 yen, with the average of 6,307 yen and standard deviation of 13,809 yen. Clearly, the incomes exhibit a lot of variances, which can also be seen in the 90-10 percentile differential, which is 8,573 yen—10,327 yen at the 90th percentile vs. 1,754 yen at the 10th percentile. Not surprisingly, both median and especially average incomes are much higher in the private sector than in academia and the public/military sectors and the variance is also much higher in the private sector (Table B1).

Table B1. Real Income Distribution by Occupations (Raw Data, Yen per Year)

Occupation	Mean	Median	St. Dev.	90th pct	10th pct	# obs.
Imperial University	4,511	3,630	3,675	7,705	1,904	972
Private Sector	10,034	4,957	21,593	20,114	1,788	1,164
Public/Military Sector	3,798	3,399	2,177	6,370	1,616	1,034

Note: Our calculations based on the data from *Who is Who in Japan* and Japan's Tax Bureau annual reports described in Appendix B.4.

Sample Selection Issues

Several issues/limitations with respect to the data from *Who is Who in Japan* need to be mentioned. To begin with, the income tax data only start from 1902 (and we are missing also years of 1904 and 1906, as mentioned in the main text). This means that for cohorts that graduated prior to 1901, we do not have their income tax (and income) data until 1902, although we do have their occupational choice data. We use information about the occupational choice in 1901 as a starting point for those who graduated prior to 1902 in the structural estimations that start from 1902.

Overall, as mentioned, we could match 258 out of 301 top graduates in our sample to *Who is Who in Japan* in at least one year between 1902-1933 (86 percent match rate). But in about 40 percent of all potential year-observations on those individuals, the income tax data are missing. This happens for various reasons, including cases where individuals would be missing from some editions for no apparent reason, or their addresses and workplaces would be listed but no income tax data would be reported.[3] There are two features of the *Who is Who in Japan* editions, however, which lead to some systematic missing income tax data which we discuss here.

First, the data collected by *Who is Who in Japan* did not cover the whole country and the areas changed over time. More specifically, the coverage included taxpayers residing in six major cities and areas surrounding them: Tokyo, Yokohama, Osaka, Kyoto, Kobe, and Nagoya, throughout our estimation period. The city of Fukuoka and the surrounding area (home to Kyushu Imperial University founded in 1911) was first added in 1919 and remained in coverage until the end of our estimation period in 1933. Other areas, however, would be included in some but not in other years. For instance, the area around the large naval facility in Yokosuka was included in the 1902-1903 editions but not in subsequent years, while the areas around naval facilities in Sasebo and Kure were included only in 1919-1922. Smaller cities such as Hachioji, Nagasaki, Hiroshima, Sendai, Kanazawa, cities in the northern-most island of Hokkaido, as well as Japanese colonies of Taiwan, Korea, Sakhalin, and the Chinese province of Kwantung were also included in coverage in some of *Who is Who in Japan* editions, (temporarily) enlarging the set of individuals for whom we could observe their income tax data.

Since we have workplaces and addresses data for all the graduates in the main panel database, we can calculate the share of observations on top graduates who resided in the areas not covered by *Who is Who in Japan* in any given year and whose income data are missing for that reason. These shares, overall and by sector of employment are presented in Table B2, while Figure B4 shows how this overall share changed over time. We can see that on average about 16 percent of observations on top graduates are on residents outside the areas covered by *Who is Who in Japan* across all years between 1902-1933 (20-25 percent in 1902-1918, dropping to 10-15 percent thereafter). Since the major Imperial Universities in Tokyo and Kyoto were always included,

[3] Some editions of *Who is Who in Japan* explicitly mention that they could not calculate the income tax paid by some individuals due to incomes from multiple sources (and corresponding multiple tax entries) which proved impossible to aggregate. We have verified that such omissions affect very high earners in the private sector, so if anything, this would bias our estimates against finding high non-pecuniary preferences for academic jobs, offsetting potential opposite biases discussed immediately below.

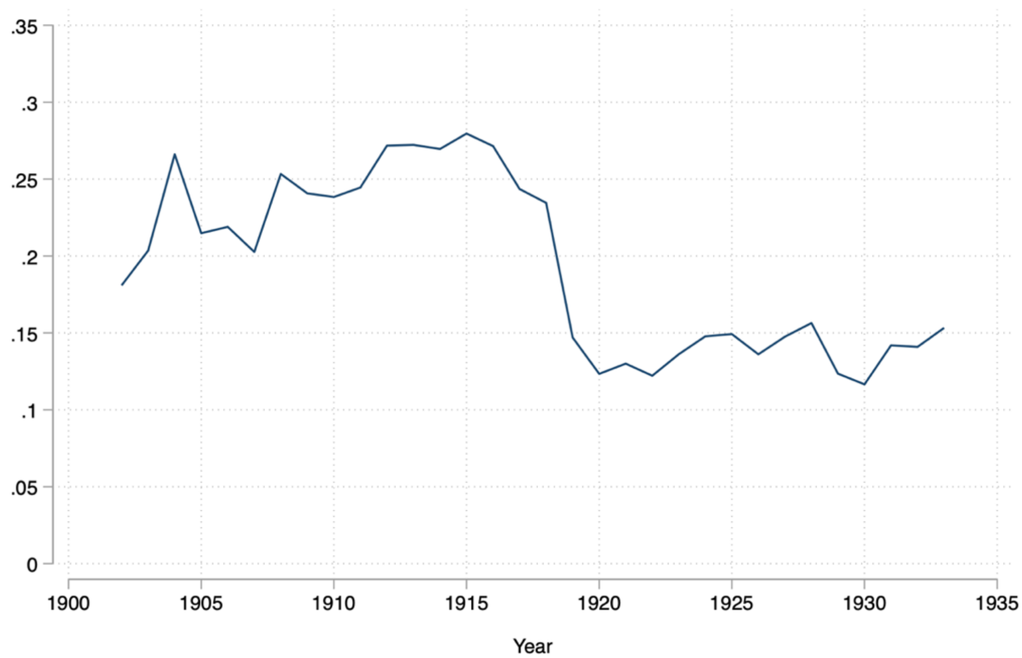
and Fukuoka hosting Kyushu Imperial University got included in 1919, this left only Tohoku Imperial University in Sendai outside of coverage for most of the time. Thus, the share of observations outside the covered areas is the lowest in the Imperial University sector (less than 10 percent). The shares of observations outside the covered areas in the private and public/military sectors are higher, but still well below 20 percent.

Table B2. Share of Observations in the Areas Not Covered by *Who is Who in Japan*

Total (%)	Imperial University (%)	Private Sector (%)	Public/Military Sector (%)
15.65	9.76	18.56	16.77
[0.43]	[0.69]	[0.73]	[0.76]

Note: The table shows the share of observations, in total and by working sector, on top graduates who resided in the areas not covered by *Who is Who in Japan* in any given year and whose income data are missing for that reason. The standard errors are in parentheses.

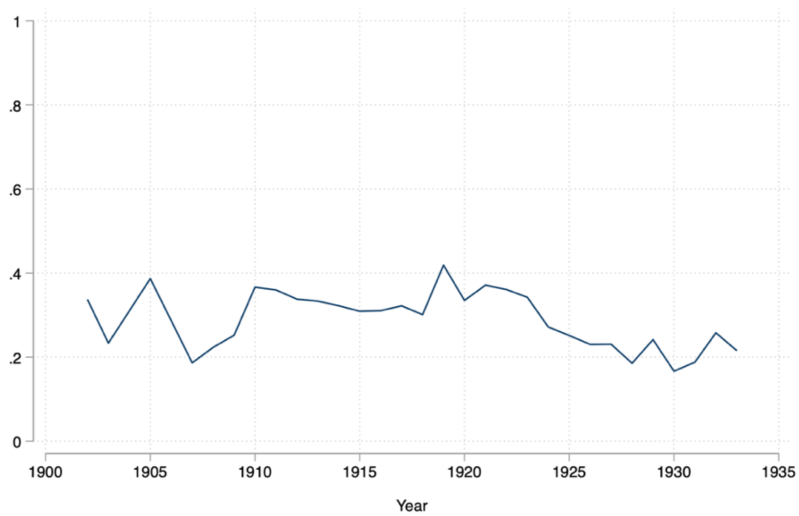
Figure B4. Share of Observations in the Areas Not Covered by *Who is Who in Japan* by Year



Note: The figure shows the overall share of observations, by year, on top graduates who resided in the areas not covered by *Who is Who in Japan* in any given year and whose income data are missing for that reason. Our calculations are based on the data from *Who is Who in Japan* and *Tokyo Teikoku Daigaku Ichiran.*

Second, *Who is Who in Japan* only included individuals above a certain income tax threshold. When it started publishing income tax data in 1902, the threshold below which individuals were not included was set at the tax amount of five yen, corresponding to 500 yen of personal income. This corresponds to salary grade 4 for assistant professors (see Table A1 above), so that the lowest-ranked assistant professors would not be included (all full professors, even at the lowest salary grade would still be covered). The income tax threshold below which individuals were not included was increased multiple times in subsequent editions, but overall, the share of top graduates in our data who resided in covered areas but whose income tax data are missing remained largely stable over time at around 30 percent (Figure B5).[4]

Figure B5. Share of Missing Observations in the Areas Covered by *Who is Who in Japan* by Year



Note: The figure shows the overall share of missing earnings observations, by year, on top graduates who resided in the areas covered by *Who is Who in Japan* in any given year but whose income data are missing. Our calculations are based on the data from *Who is Who in Japan* and *Tokyo Teikoku Daigaku Ichiran*.

As mentioned, individuals could be missing from *Who is Who in Japan* despite residency in areas included in coverage for various reasons, not just because their income tax was below the threshold. However, inasmuch as income data are missing due to income tax below the threshold, this does create a potential sample selection issue since we may be missing information on very low earners. Since our structural estimation of occupational choice relies on comparing earnings across different sectors of employment, it would not necessarily present a problem if the observations were missing in similar ways for academia as well as non-academia. Table B3 shows, however, that we tend to be missing relatively more year-income observations among the individuals residing in areas covered by *Who is Who in Japan* in the private and public/military sector (30-33 percent) compared to academia (22 percent). In turn, this seems to be due to two factors.

Table B3. Share of Missing Observations in the Areas Covered by *Who is Who in Japan*

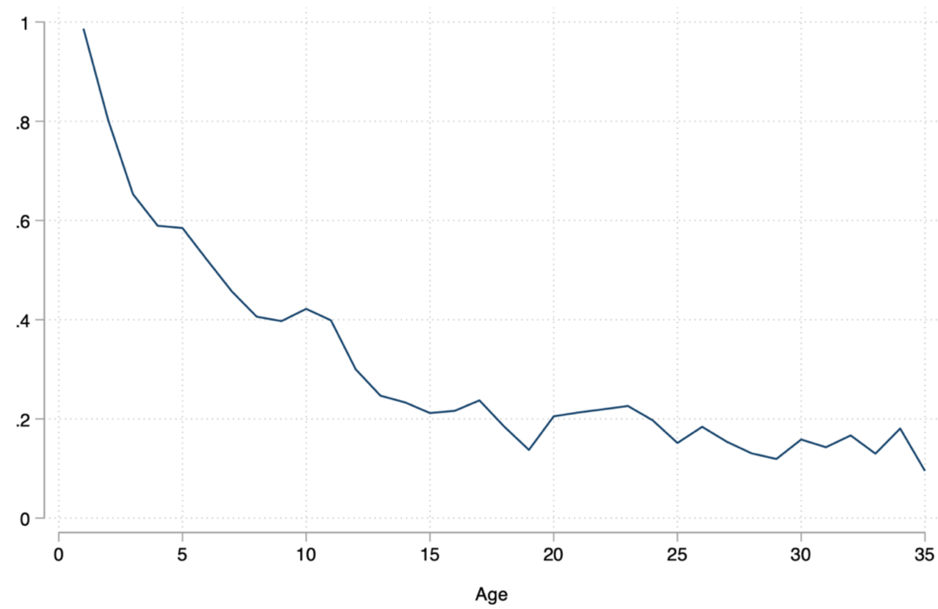
Total (%)	Imperial University (%)	Private Sector (%)	Public/Military Sector (%)
29.34	22.12	30.67	33.68
[0.68]	[1.18]	[1.13]	[1.20]

Note: The table shows the share of observations, in total and by working sector, on top graduates who resided in the areas covered by *Who is Who in Japan* in any given year but whose income data are missing. The standard errors are in parentheses.

[4] The slight decline in this share in the 1920s-early 1930s is explained by the fact that no new cohorts were added past 1918 while individuals become more likely to have incomes above the threshold as they age. We discuss this in the context of the relationship between missing year-income observations and age immediately below.

First, as can be seen from Table B1, earnings in the private sector exhibit higher variance. Thus, there could be relatively more observations where top graduates employed in the private sector would not meet the inclusion criteria in *Who is Who* in that particular year. As Table B3 shows, we have about 10 percentage points more observations on individuals who reside in covered areas but for whom we have missing income data in the private sector than in Imperial Universities.

Figure B6. Share of Missing Observations in the Areas Covered by *Who is Who in Japan* by Age

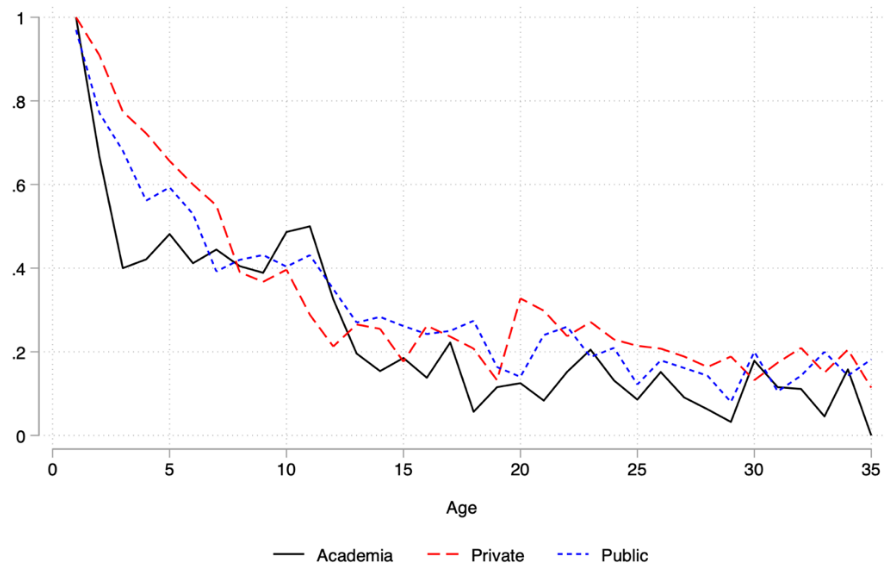


Note: The figure shows the overall share of missing earnings observations, by year after graduation, on top graduates who resided in the areas covered by *Who is Who in Japan* in any given year but whose income data are missing. Our calculations are based on the data from *Who is Who in Japan* and *Tokyo Teikoku Daigaku Ichiran.*

Second, as earnings increase with age (experience), our top graduates are less likely to clear the threshold for being included in *Who is Who in Japan* while they are still young. Figure B6 shows the relationship between age (years after graduation) and the empirical probability of having non-missing income-year observations in our data. We do not have observations on income tax data for almost anyone in the first couple of years, but then the share of missing income observations quickly declines and stabilizes at around 20 percent after about 13 years. Hence, and in contrast to most extant studies which examine early career choices, our estimations of occupational choice rely mostly on data points pertaining to mid- later-career observations, with earnings at younger age extrapolated from the fitted parameters of the model.

Figure B7 breaks down the age distribution of missing year-income observations by three occupational sectors. While we miss relatively more top graduates employed in the public/military and especially the private sector up until post-graduation year seven, beyond that the patterns are similar, so that all sectors are more or less equally affected by missing incomes at younger ages.

Figure B7.
Share of Missing Observations in the Areas Covered by *Who is Who in Japan* by Age and Sector



Note: The figure shows the shares of missing earnings observations, by year after graduation and by each sector, on top graduates who resided in the areas covered by *Who is Who in Japan* in any given year but whose income data are missing. The black solid line, red long-dashed line, and blue short-dashed line represent academia, the private sector, and the public sector, respectively. Our calculations are based on the data from *Who is Who in Japan* and *Tokyo Teikoku Daigaku Ichiran*.

B.4. Matching with Patent Publication Records

In the main text we made use of the matched data set between the panel data on engineering graduates and patent data from the Japan Patent Office, available from the Patent Information Platform (J-PlatPat) operated by the Industrial Property Information and Training Institute (INPIT, https://www.j-platpat.inpit.go.jp/). The collaborating team in Japan shared with us the digitized bibliographic information recorded in all patent specifications for patents granted between 1885 and 1940 (around 126,000 patents), which include patent numbers and titles, technology classes, inventors' and assignees' names and addresses. We then hand-matched the information in the patent data with our database of engineering graduates. Different combinations and old forms of characters in which names were written were considered and name changes of university graduates were tracked by extensively investigating various sources, including Calendars of Imperial Universities, public high schools, Japanese Personnel Inquiry Records (*Jinji Koushinroku*), and online searches. To avoid false matches of same-name but different individuals, we manually checked the consistency of employer and address information between the graduates' records and the patent records for all individual matches and dropped those where we were not sure that it was the same person (the fraction of cases dropped through this manual check was about 10 percent of the total number of initial matches).[5]

[5] In determining if the patent record belonged to a given graduate or not we chose to err on the side of caution and rejected a match if we could not definitively ascertain that we had a positive match.

C. Illustrative Cases

This appendix describes some case evidence that support our argument in the main text.

C.1. Difficulty in Retaining Top Talent: Ichisuke Fujioka

The case of Ichisuke Fujioka who graduated at the top of his cohort from the Electrical Engineering division of what at the time was Imperial College of Engineering in 1881 is cited in the main text as an example of the difficulty the University had in retaining top talent early on. Fujioka worked as faculty at the Imperial College of Engineering after his graduation and was then appointed as an Assistant Professor at the Department of Engineering at Tokyo Imperial University when it was established in 1886. His status was that of Category Five Senior Civil Servant (Segawa, 1933) which at the time paid annual salary between 700-900 yen (*Tokyo Teikoku Daigaku Goju-nenshi*, Vol. I, p. 954). He resigned in less than a year, however, to become the chief engineer at Tokyo Electric Light Company, one of the first private electric utility companies in Japan. His biographers do not tell us how much the utility company paid him, but we have the data on the salaries of two chief engineers at cotton spinning firms in the same year. Tsunezo Saito, who graduated a year later than Fujioka and not at the top of his class but as number four out of six graduates, was paid 75 yen per month (900 yen annualized) as the chief engineer of Mie Spinners (Mie Spinners Company Report #2, available upon request), while Kyozo Kikuchi, who graduated two years later than Fujioka as number two in the class of three, was paid 100 yen per month (1,200 yen annualized) as the chief engineer of Hirano Spinners (Hirano Spinners Company Report #1, available upon request). Given Fujioka's higher status and the fact that the utility which hired him was much larger than either of the above two cotton spinning firms, we can assume that he was offered a significantly higher salary than he had been receiving as engineering faculty. But even at 1,200 yen, the salary offered by the utility company would have been 50% higher than the salary offered by the University.

C.2. "Shaping" the Rules of the Game: Faculty Fight for Self-Governance

In this part of the Appendix we discuss in some more detail the evolution of academic freedom and autonomy in the Imperial University system, briefly outlined in Section V.2 of the main text, which served as a critical pre-requisite for increased non-pecuniary "payoffs" from academic jobs as well as shift toward research focus described in Sections V.3-V.4 of the main text.

The 1893 Imperial Edict took a major step toward raising the social status of the academic profession by stipulating that up to 12 professors could become Emperor-appointed civil servants (*Chokuninkan*), a status previously reserved only for the University President (*Tokyo Daigaku Hyakunenshi*, 1977, Vol. 1, p. 824-825); the restrictions on the number of such appointees were subsequently lifted. Also, while the edict did not go as far as to separate the university from the government as envisaged in the faculty-drawn reform proposal, it did redefine the role of the University President from "*acting on the orders from the Minister of Education*" to "*acting under the supervision of the Minister of Education in accordance with the provisions of the Law on Imperial University*." It also stipulated that Deans of various colleges could be selected from only among the faculty, ending the practice of outside political appointments (*ibid.*, pp. 845-846). Perhaps most importantly, the edict legally codified the role of faculty assemblies for the first time. While the assemblies were initially only given a say in curriculum-related affairs, once codified, it set the stage for later expansion of the span of their authority and laid the foundation for the self-governance system still in place in Japan's academia today (*ibid.*, pp. 849-851). For instance, five years later, in 1898, faculty assemblies were given independent decision-making power on academic degrees.

The above changes in administrative autonomy were accompanied by redefining academic purpose to include research, concomitant with structural changes and financial support. Together, this increased the attractiveness of faculty jobs for top-talented individuals who saw clear pathways for internal promotion. As mentioned in the main text, starting from around the turn of the 20th century, Imperial Universities adopted a systematic approach to such promotion: young assistant professors (typically a few years in their jobs) were given paid sabbaticals for two to three years to stay at top universities and research institutes in Europe or the United States. Upon returning (and occasionally even during those sabbaticals), they were promoted from assistant to full professors, and subsequently awarded doctoral degrees.[6] Given the clear expectation of upward career mobility within academia, young top-talented individuals who had previously considered changing careers after returning from a study-abroad stint (Terasaki, 2000) now found faculty jobs particularly appealing (Iwata, 2021, pp. 84-85). An important element in efforts to nudge talented individuals to choose academic careers occurred during their student years itself by creating an "honor students" (*tokutai gakusei*) system. Honor students, designated by the Deans, subject to the University President's approval, were selected based on academic achievement and exemplary behavior, and they received tuition waivers (*Tokyo Daigaku Hyakunenshi,* 1997, Vol. 7, p. 633). About half of all eventual top graduates in our data were designated as honor students at the end of their second year.

Beyond the initial reform proposals and subsequent internal changes, the fight for autonomy and self-governance manifested in at least two recorded conflicts that became particularly important milestones in the path for how the University Presidents were themselves selected. Those two milestones in the faculty fight for autonomy are called in Japanese historiography the "Tomizu incident" (*Tokyo Daigaku Hyakunenshi*, 1977, Vol. 2, pp. 161-170) and the "Sawayanagi incident" (*Tokyo Daigaku Hyakunenshi*, 1977, Vol. 2, p. 4; *Kyoto Daigaku Hyakunenshi,* 1997, Ch. 3).

The Tomizu incident started in 1905 when Hirondo Tomizu, a professor in the Tokyo Imperial University College of Law was suspended for political expressions made outside of the university. This led to an open conflict between the faculty and the administration supported by the Ministry of Education. One hundred ninety faculty members from multiple colleges comprising the University signed a petition to the Prime Minister demanding that Tomizu be reinstated. The pressure from the faculty first forced the resignation of the

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[6] At the time doctoral degrees in Japan were awarded predominantly mid-career, based on recommendation of committees comprised of senior peers or upon submitting doctoral dissertations (Nakayama, 1978; Amano, 2004, Vol. 1).

University President. The Prime Minster also relieved the Minister of Education of his duties while Tomizu was reinstated. Thus, the first serious test case of the freedom of expression ended in a decisive victory for the faculty.

The "Sawayanagi incident" started in 1913. Sawayanagi was just installed as the new President of Kyoto Imperial University when he fired seven professors from several departments, including one who was a prominent advocate for faculty independence. By that time, the faculty assemblies' role in making personnel decisions had already become an informal, although not yet codified norm. Protesting the firing, all Kyoto Imperial University College of Law core faculty members submitted a collective resignation letter. They also received strong support from Tokyo Imperial University. Once again, the faculty won: Sawayanagi was relieved of his duties, and the Minister of Education issue a written opinion that read: "*when exercising personnel decisions with respect to professorial positions in accordance with his duties, the University Presidents can and should seek consent from college faculty assemblies*" (*Kyoto Daigaku Hyakunenshi,* 1997, Ch. 3, p. 230). Furthermore, the system of appointing University Presidents by the government itself was replaced by the direct vote of all professors (legally codified in 1918 but de facto implemented already starting from 1914—*Tokyo Daigaku Hyakunenshi*, 1977, Vol. 2, pp. 285-286).

While both incidents above did not directly involve engineering faculty, the big changes in the governance structure that were ushered in as a result of wins by the faculty reverberated across the whole system. In particular, as mentioned in the main text, electing university presents by direct faculty vote is still common practice in Japanese academia today.

C.3. University Careers of Industry Innovators: Kyoji Suehiro and others

Here we first present more biographical details about Kyoji Suehiro mentioned in the main text as an example of top faculty partnership with an industry firm. Suehiro was the top-ranked graduate from the Naval Architecture division of the Engineering Department in 1900. In Table C1 below we have summarized specific events from his career timeline.

Suehiro joined the Tokyo Imperial University engineering faculty in 1902 after working one year for Mitsubishi Shipbuilding Co. His income in 1902-1905 corresponds to the salary schedule for an assistant professor in those years, inclusive of service allowance (see Table A1 and the discussion in the main text). Most of the increase observed in 1907-09 (prior to the sabbatical) can also be accounted for by the general salary increase and more incentives for teaching introduced by the University in 1907. In accordance with the practice established in the early 1900, the University sent him on a two-year sabbatical to England and Germany to study applied mechanics. During this sabbatical he was awarded doctoral degree. After coming back in late 1911, Suehiro was promoted to full professor and his salary almost doubled, commensurate with the difference between assistant and full professor salary scales (*ibid*.). All in all, through the first 12 years of his academic career, Suehiro had been earning salaries that any productive faculty member would expect in his place.

During his sabbatical, Suehiro started conducting research in rotary-transmission dynamometer which eventually won him the Imperial Academy Prize (the most prestigious academic prize in Japan). He also patented this invention in Japan, Great Britain, and the United States in 1912 (the patent was granted in Japan in the same year and in 1913 and 1914 in Great Britain and the U.S., respectively). We can see some increase in his income, which may be due to a bonus from the university, in 1914, although the increase is modest. Several years later (in 1919-1920), however, his earnings increase by much more than implied by the University salary increase in Table A1. Those were the years when according to his biography, he re-established research-based collaboration with Mitsubishi Shipbuilding. In particular, in late 1918, Mitsubishi Shipbuilding accepted Suehiro's proposal to establish the Mitsubishi Shipbuilding Research Institute, and he became the first head of that institute. Even though he did not stay in this position for long, Suehiro remained a consultant for Mitsubishi Shipbuilding and all his subsequent patents were assigned to that company. As mentioned in the main text, he was also one of the initiators of the Institute of Seismology and served as the director of that Institute, affiliated with Tokyo Imperial University in from 1925 and until he passed away in 1932. As can be seen from Table C1, all this appears to have contributed to earnings way above the standard salary of an engineering faculty professor throughout the 1920s. All in all, we see extra income based on complementary assets and university-industry collaboration, accruing to a star faculty, to complement non-pecuniary attractiveness of a faculty job.

The list of senior faculty members with important roles in advising private-for-profit firms and helping them develop new technologies as well as recruiting top talent from among students includes many prominent scholars, such as Ariya Inokuty who founded EBARA jointly with his student, Issei Hatakeyama (see footnote 6 on p. 17 of the main text), Jinkichi Inoue, dubbed by his biographers "the leading light in Japan's dye chemistry" (Shibata, 1961, p. 56), Iwata Nakazawa and others. We present here some details about the role played by Nakazawa and his disciples; details of other stories are available upon request (see also Kamatani, 2006).

Iwata Nakazawa was the 1879 top graduate from the Chemistry Division of what was the University of Tokyo at the time (before the inauguration of the Imperial University). He worked in academia his whole life but played an important role in the inception of chemical industry in Japan both on his own and through his students. Nakazawa was appointed to be professor of applied chemistry at the just-inaugurated Imperial University in 1887. In 1889 he helped found Nippon Seimi Seizo, the first private company to produce sulfuric acid and caustic soda in Japan. According to his biography (*Nakazawa Iwata Hakase Kiju Shukuga Kinencho*, 1935), he not only participated in choosing the location and selecting workers and technicians for the firm to hire, but, importantly, directed his students, Sentaro Tsuboi, Iwaichiro Shitsuki, and Torakichi Nishikawa to join the company. Between 1890-1896 he also worked on a contract bases for the first government establishment to produce sulfuric acid in Japan, even serving as its director for one year in 1894, all while maintaining his primary job at the Imperial University. Later, after the outbreak of World War I, he served on the Chemical Industry Research Committee set up by the Japanese government following the disruption of imports from Europe and as an advisor to a private company, Asahi Glass (see immediately below).

In turn, the students whom Nakazawa directed to Nippon Seimi Seizo followed in his footsteps by combining academic pursuits with important industry work. The most prominent among them was Torakichi Nishikawa, 1893 top graduate. After a two-year stint as an assistant professor at his *alma mater* he signed a contract with Nippon Seimi Seizo mediated by Nakazawa (*Nishikawa Torakichi Hakase Tsuisoroku*, 1951, p. 400). In the contract, the company offered him the initial salary of 80 yen per month (which is similar to Suehiro's 1905 income—see Table C1) and committed to sending him for a two-year study abroad. Upon his return, Nishikawa became chief engineer and was then promoted to Executive Director in 1905. His work on improving soda production technology in Japan already started at that time[7] but really took off after he returned to academia in 1909. He first went back to Tokyo Imperial University and went to Europe to visit Solvay, the leading soda producer, to try to forge technological collaboration to implement Solvay (ammonia soda production) method. After Solvay refused to cooperate, Nishikawa felt like that left him no option but try to develop this technology on his own (*ibid.*, p. 408). In 1911 he became the professor in charge of applied chemistry chair in the newly established Kyushu Imperial University and in 1914 joined the Chemical Industry Research Committee (see above) together his former advisor, Nakazawa. After the proposal by the Committee to set up a government-run experimental factory went nowhere, Nishikawa, together with Nakazawa and another life-time academic became advisors to Asahi Glass, which started building the first factory to produce soda by the ammonia method in Japan in 1915 (*ibid.*, p. 416). Nishikawa is widely credited with helping this endeavor to succeed. He later served as the Dean of the Engineering Department and the President of Kyushu Imperial University before retiring in 1929.

The other two students Nakazawa recommended to Nippon Seimi Seizo in the early 1890s also had illustrious careers spanning industry and academia. Both also worked as Nippon Seimi Seizo chief engineers for several years. Tsuboi then went on for a lifetime of teaching at Osaka Technical College (currently Osaka Institute of Technology) where he founded a brewing division, invented a new method of producing sake, widely adopted by Japanese brewers and developed a chemical ingredient that his nephew, a graduate of the same division, utilized in creating a company producing an energy drink. After two years as assistant professor at the Imperial University, followed by three years as chief engineer of Nippin Seimi Seizo, Shitsuki also moved back into teaching and becoming the director of Ishikawa Technical College.

[7] Nishikawa's initial research in this technology was outsourced to Kamejiro Yoshikawa, a professor at Kyoto Imperial University at the time (*Nishikawa Torakichi Hakase Tsuisoroku*, 1951, p. 403). Yoshikawa is another early example of an academic engineer who contributed to the development of an important industry technology. He graduated at the top of his cohort from the same applied chemistry division as Nishikawa two years later, in 1895. While Yoshikawa's research conducted jointly with Nishikawa and Nippon Seimi Seizo did not lead to immediate commercialization, once imports of ash soda from Europe were temporarily interrupted after the start of World War I, the mercury process technology he developed was commercialized by the newly founded Osaka Soda Company in 1915.

Table C1. Kyoji Suehiro's Timeline and Earnings

Year	Patents	Job title	Doctoral degree	Sabbatical abroad	Income tax paid (yen)	Calculated income (yen)
1902	0	Asst. Prof.	0	0	10	833
1903	0	Asst. Prof.	0	0	10	833
1904	0	Asst. Prof.	0	0	No data	
1905	0	Asst. Prof.	0	0	23	968
1906	0	Asst. Prof.	0	0	No data	
1907	0	Asst. Prof.	0	0	53	1,767
1908	0	Asst. Prof.	0	0	55	1,833
1909	0	Asst. Prof.	1	1	55	1,833
1910	0	Asst. Prof.	1	1	na (sabbatical)	
1911	0	Professor	1	0	na (sabbatical)	
1912	1	Professor	1	0	99	2,912
1913	0	Professor	1	0	101	2, 912
1914	0	Professor	1	0	102	2,933
1915	2	Professor	1	0	89	2,644
1916	1	Professor	1	0	89	2,644
1917	0	Professor	1	0	78	2,400
1918	1	Professor	1	0	86	2,291
1919	0	Professor	1	0	291	5,306
1920	0	Professor	1	0	291	6,846
1921	0	Lecturer	1	0	32	2,025
1922	1	Professor	1	0	230	5,908
1923	0	Professor	1	0	1,393	18,428
1924	0	Professor	1	0	1.132	16,055
1925	0	Professor	1	0	497	9,450
1926	1	Professor	1	0	440	8,738
1927	3	Professor	1	0	799	12,716
1928	0	Professor	1	0	758	12,284
1929	0	Professor	1	0	876	13,526
1930	3	Professor	1	0	898	13,758

C.4. Academic Research Institutes

In this section we describe brief histories of major academic research institutes discussed in Section V.4.

1) Institute of Aeronautics (Tokyo Imperial University)

The roots of this institute can be traced to 1909 when Temporary Military Balloon Study Group was established by an Imperial Edict. The Group was led by the army (ground forces) but it also included navy as well as senior faculty members from Tokyo Imperial University, two of which hailed from the College of Engineering: Inokuty Ariya from the Mechanical Engineering division and Seinen Yokota from the Naval Architecture division. While the Study Group was formally tasked a with a broad range of research topics, including balloons and aero planes, as well as navigation and communication technology, the army and navy repeatedly clashed over priorities, with the army favoring balloons and the navy favoring aircraft. (Chida, 2021). The group de facto fell apart in 1915 over these disagreements (it was formally liquidated in 1920) but growing awareness of the importance of aviation, especially triggered by its successful use on the battlefields of World War I prompted Inokuty and Yokota to urge the power that be to set up an independent research group to study aeronautics in academia. They pitched the proposal to Kenjiro Yamakawa who was the President of Tokyo Imperial University at the time. Yamakawa accepted the proposal and the Commission for the Study of Aeronautics within the Naval Architecture division of the College of Engineering was established in the fall of 1916 (*Tokyo Daigaku Hyakunenshi,* 1997, Vol. 7, p. 321-322). The Commission, led by Yokota and Inokuty (alongside with Aikitsu Tanakadate, a senior professor of physics in the College of Science) recruited several young researchers, including two engineers who were recent top graduates, Toyotaro Suhara (a 1910 graduate from the Mechanical Engineering division) and Koroku Wada, a 1915 graduate from the Naval Architecture division (both stayed to later become full-time core engineering faculty) and began to work on aerodynamics and high-altitude engines using space in a corner of the College of Engineering experiments lab and the storage room in the basement of the adjacent Faculty of Law (Suhara, 1961, p. 1). At the same time, the commission prepared a proposal for the formal establishment of the Institute of Aeronautics and its budget, which was submitted to the government and both chambers of the Japanese Parliament. As a result, the law formally ordaining the Institute in affiliation with the College of Engineering was enacted in 1918.

As mentioned in the main text, the organizational structure of the Institute of Aeronautics was unique in that it was the first University-affiliated research institute whose full-time researchers were recruited from academic faculty and could work at the Institute full-time while retaining the full academic status. A such, the Institute provided strong incentives for engineering faculty, especially in Mechanical Engineering and Naval Architecture, the fact that was exploited in causal inference analysis in Section V.4.1 of the main text.

2) Institute of Material Research (Tohoku Imperial University)

Tohoku Imperial University, established in 1907, initially did not have an engineering department but by the mid-1910s, establishing such a department was put on the agenda. Junkichi Inoue, a senior faculty member of Tokyo Imperial University School of Engineering recommended his former student, Sadakichi Sato, a 1912 top graduate in applied chemistry, to join Tohoku Imperial University faculty as a core faculty member with a view to becoming a lead faculty in the new School of Engineering (Kamatani, 2006). At the time Sato was conducting research on producing celluloid-like materials from vegetable proteins such as soybeans. Sato arrived at Tohoku Imperial University in September 1914 and applied for a patent on his research in November the same year. In April 1915 Inoue and Sato, together with the University President Tokiyuki Hojo paid a visit in Tokyo to Sankyo Corporation (https://daiichisankyo.us), a venerable Japanese drug maker, which was just incorporated the year before to become a diversified chemical industry producer, and discussed Sankyo's sponsorship of the research by Sato into non-flammable celluloids with Sankyo's co-founder and CEO, Masataku Shiobara, The written agreement with Sankyo was signed on April 30 whereby Sankyo donated 15,000 yen to support Sadakichi Sato's research (*ibid*., p. 84). The University president then contacted the Ministry of Education which approved the establishment of the Temporary Institute for Physical and Chemical Research affiliated with the University in August the same year. This led to the establishment in August 195 of the Temporary Institute for Physical and Chemical Research, an internal research organization within Tohoku Imperial University.

In parallel with this, Hojo (the University President) also pitched the idea of supporting university-based research to his contacts in Sumitomo corporation, one of the largest diversified business groups (*zaibatsu*) in Japan. Even prior to that, in July of 1914, the university president conducted negotiations with the Sumitomo group to solicit support for steel-related research by another professor, Kotaro Honda, the 1897 College of Physics graduate and Tohoku Imperial University professor since 1911. Following this second large donation the Temporary Institute for Physical and Chemical Research was reorganized to consist of two departments (one related to Sato's and the other to Honda's research agenda). Three years later, in 1919, the Sumitomo group donated 300,000 yen for the Institute building, equipment and operating expenses and the Tohoku University Institute of Steel was officially inaugurated by the Imperial Edict (expanded and renamed The Institute of Material Research by another Imperial Edict in 1922). (Kamatani, 2006.)

As can be seen from this timeline, the Institute originated from the support by private companies for industry-related technology research. Their success created the basis for continued basic industry-related research at Tohoku Imperial University, supporting by flows of donations from various private companies and foundations (Table C.2). The Institute also transferred a lot of its patents to private companies, both incumbent firms such as Sumitomo Metals and startups, most of which were created in Sendai where the University was located, creating an industrial cluster (Kamatani, 2006, p. 93). We do not have the data on how much revenues from those patents contributed to the Institute's budget but we do have the data on *Riken* (see below) which shows that toward the 1930s up to half of its total revenues came from patents. The number of patents generated by academic faculty in Tohoku Imperial University Institute of Material Research was comparable to *Riken*; therefore, we can conjecture that it was a major source of their research budget as well.

3) Institute of Chemical Research (Kyoto Imperial University)

This Institute's story was in many ways similar to the Institute of Material Research above. Japan had relied on imports from Germany in most of its pharmaceuticals, but those imports took a big hit at the start of World War I. One particularly important drug whose imports were eliminated was Salvarsan (arsphenamine), a recently developed drug to tread syphilis. In January 1915 two faculty members of Kyoto Imperial University College of Science and Engineering, Mitsuru Kuhara and Kaoru Matsumia started research into developing a domestic substitute for Salvarasan. By May of the same year they succeeded in synthesizing some major components, which led to setting up what was at the time called Special Institute for Chemical Research affiliated with the Chemistry division in the College of Science and Engineering, financed largely by private donations. The Institute kept adding more researchers and research directions. While much of the research conducted at this Institute was science and medicine-related, it also employed several prominent engineering faculty, such as Genitsu Kita whose research spanned man-made fibers and fuel (he also became the Institute director in 1930), Toshio Watanabe who did basic research in non-ferrous metallurgy and others.

4) Institute of Seismology (Tokyo Imperial University)

On September 1, 1923 an M8 earthquake hit Tokyo. More than 100,000 people died and the destruction was widespread and devastating. In the wake of this disaster, two senior faculty members of Tokyo Imperial University, Kyoji Suehiro from the College of Engineering and Torahiko Terada from the College of Science proposed the creation of a new Institute of Seismology. Their idea was to combine fundamental research into seismology with the research into practical aspects of controlling the damage from future earthquakes, and to recruit top specialists from around the country as well as teach new generations of young researchers. Their plan received support from Masatoshi Okochi who headed Riken and was also a member of House of Peers (see below about Okochi), and the corresponding legislation was adopted by the Japanese Parliament 1924 and the Institute officially inaugurated the next year.

As can be seen from the fact that Suehiro whose main job was in Naval Architecture was appointed as the first director, the Institute made a deliberate effort to put scientists and engineers who were not narrow specialists in seismology in key positions. This was done to approach the study of earthquakes from a perspective different from extant seismological science (*Tokyo Daigaku Hyakunenshi,* 1997, Vol. 7, p. 330).[8] The same rules as in the Institute of Aeronautics were applied well, meaning that the Institute could hire core science and engineering faculty members full-time, with relief from teaching and other departmental duties. The Institute governance rules also opened the door for hiring faculty from other Imperial Universities to recruit the best of the best in the profession, not limiting the choice to faculty of Tokyo Imperial University only.

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[8] Other key personnel included Yozo Uchida, professor in the division of architecture, Torahiko Terada, professor in the division of physics, as well as specialists from outside the Imperial University system such as head of the Central Meteorological Observatory. The Institute did include seismology professor Akitsune Imamura, however, who famously predicted that a devastating earthquake was going to hit the Tokyo area within 50 years in 1905.

5) Institute of Physical and Chemical Research (*Riken*) and Masatoshi Okochi

As mentioned in the main text, *Riken* was founded as a private institution in 1917. It was modeled after the Kaiser Wilhelm Society in Germany and was run by the Imperial Universities' faculty and basically served as the vehicle for research for its faculty. Being a privately funded institution, it struggled both financially and organizationally for the first several years, however. Constant fighting for budget resources between the physics and chemistry departments also took a toll.

In September 1921, Masatoshi Okochi was appointed *Riken's* third director, and this became a turning point in its history (Riken, 2009). Okochi (1878-1952) was a top graduate from the ordnance division of the College of Engineering in 1903. His career is an example of the academic "career escalator" in place since the early 20th century (see Section V in the main text). He was hired as a lecturer in the College upon graduation, became assistant professor the next year and was promoted to full professor in 1911 following a two-year sabbatical in France. A prolific inventor, Okochi had 73 domestic and 14 global patents over his career. As he was appointed the director of *Riken*, he declared in his inaugural address:

"*The direction in which I will take the institute is designing methods to combine scientific research and practice, and through this to create the foundation for industries. This would mean close contacts with the business sector and would require certain expenses, but that is inevitable. As for researchers, research is our lifeline which is why I hereby declare my intention to let go those who cannot endure research work or do not have ability to do so and instead bring in energetic and talented researchers."* (Riken Seishin 88-nen, 2005, p. 7)

Okochi's first act as the director was to abolish the warring physics and chemistry departments. In their place, he established a system of independent labs, each led by a Chief Scientist recruited from among the best Imperial Universities' professors, were given autonomy to manage research topics, personnel and budget (Riken, 2009, p. 35).

The outcome was an explosion in innovative activity. As mentioned in the main text, 32 Imperial University faculty members from our panel data joined *Riken* labs since its inception and continued after Okochi became the director. Regression estimations controlling for year and individual fixed effects (not shown) indicate that after they joined *Riken*, the number of patents they applied for in any given year jumped four times (from 0.07 to 0.27 patent applications per year). Splitting the years spent in *Riken* into those before and after Okochi's reforms shows that most of the increase happened following Okochi's ascendance to presidency—the number of patent applications per year doubled from prior to 1917 to the 1917-1921 period and it more than doubled once again in the 1922-25 period. Moreover, many of those patents were co-inventions with students whom the professors could now hire as research assistants at *Riken* (details are available upon request).

Okochi leveraged the research output to set up a group of companies that became known as "RIKEN Konzern" (Riken, 2009, p. 36) tasked with commercializing patented inventions produced by *Riken's* scientists and engineers. Okochi assumed the positions of the chairman in most of those companies to make sure *Riken* could exert strong influence over them. By 1935 there were eight companies, the number of which grew to 15 in the next year and to 32 in 1937 (*ibid.*). Okochi had served on Tokyo Imperial University faculty for 22 years

Research Institutes Patent Assignment Rules

Below are some excerpts from the rules governing the assignment of patents based on inventions made by researchers working at academic research institutes. The particular source (translated from the Japanese by the authors) is the 1929 *Tohoku Teikoku Daigaku Kinzoku Zairyo Kenkyujo Yoran* (Institute of Material Research, Tohoku Imperial University Annual Calendar, p. 27-30), available online at https://dl.ndl.go.jp/pid/1191312/1 but the wording in the all the published rules by other institutes we examined (including Riken) is exactly the same.

Rules pertaining to inventions, utility models, and designs produced by the employees of the Institute of Material Research

"1) If an Institute employee developed an invention in the process of his work at the Institute, the right to the patent belongs to the Institute. This also applies to patents granted in foreign countries.

2) Patent rights to inventions mentioned in the previous paragraph can be assigned jointly to the Institute and the inventor if the inventor desires and the Institute agrees.

…

4) When the Institute receives rights to patents as per 1) above, the compensation to the inventor consists of 50 percent of all of the below: profits from implementing the inventive patent [that is, revenues from commercialization by the patent holder, i.e., the Institute itself – S.B.]; payments received as compensation for allowing the use of the patent; payments received as compensation for the use of the patent by entities having the legal right to use the patent; [the above two can be considered royalties received from third parties, with the difference being that some third parties apparently had the right to use patents granted by the law – S.B.]; payments received from transferring the rights granted by the patent and patent rights themselves; payments received from the government as compensation for restricting the use of patent or its cancellation. This 50 percent rule can be adjusted by 10 percent up or down in consideration of the circumstances surrounding the patent if the Institute determines such circumstances warrant the adjustment.

In case of joint invention by several Institute employees, the above total compensation is allocated to each inventor by the Institute's decision.

If the patent is co-assigned to both the Institute and the inventor as per 2) above, the compensation to the inventor(s) consists of the share of patent rights."

Rules pertaining to granting rights to use inventions, utility models, and designs produced between the Institute of Material Research and Research Sponsors / Sponsored Research Fellows

"1) If an Institute employee developed an invention in the process of his work on the research sponsored by a government agency, firm, or individual, the right to the patent belongs to the Institute. This also applies to patents granted in foreign countries.

2) When the Institute receives patent rights to an invention in the previous paragraph it informs the sponsoring party.

3) If the sponsoring party requests the right to use the inventive patent within six months from the notification per the previous paragraph, the Institute will confer with the sponsoring party about various conditions of using the patent, including the time period, area, and ways of practical implementation, as well as the amount of compensation. If an agreement is reached, the Institute will prioritize the usage of the patent by the sponsoring party and will not permit the usage of patent by third parties.
4) If permission to use the patent is given to the sponsoring party as per the previous paragraph, the Institute own use of the patent is limited by the agreed terms.
5) In case the Institute permits the use of the inventive patent to the sponsoring party as per paragraph 3), the sponsoring party pays the Institute at least 30 percent of the profits from the use of the inventive patent.
6) Ten percent of the capital investment made to use the patent in the previous paragraph will be deducted from the amount of profit in the previous paragraph.
Same rules apply to inventions by research fellows sponsored by third parties."

Further provisions (not shown in detail) provide the details of accounting periods to be used to calculate profits as well as the right of the Institute to revoke the right to use the patent and demand compensation if the Institute decides that the sponsoring party is not making good-faith effort to use the patents the usage right of which were granted to it.

Table C2. Donations to Tohoku Imperial University Institute of Material Research

<table>
<tr><th>Donor</th><th>Amount (yen)</th><th>Year</th></tr>
<tr><td>Kichizaemon Sumitomo[*]</td><td>21,000</td><td>1918</td></tr>
<tr><td>Kiso Electric Industries, Inc.</td><td>10,000</td><td>1920</td></tr>
<tr><td>Saburo Watanabe[†]</td><td>2,000</td><td>1920</td></tr>
<tr><td>Kichizaemon Sumitomo</td><td>150,000</td><td>1919-1921</td></tr>
<tr><td>Kichizaemon Sumitomo</td><td>100,000</td><td>1919-1921</td></tr>
<tr><td>Kichizaemon Sumitomo</td><td>50,000</td><td>1919-1921</td></tr>
<tr><td>Mitsubishi Shipbuilding, Inc.</td><td>1,000</td><td>1919</td></tr>
<tr><td>Kobe Steel, Inc.</td><td>10,000</td><td>1921</td></tr>
<tr><td>Tsunesada Sangawa[‡]</td><td>2,000</td><td>1921</td></tr>
<tr><td>Mitsubishi Shipbuilding, Inc.</td><td rowspan="4">10,000</td><td rowspan="4">1922</td></tr>
<tr><td>Mitsubishi Steel, Inc.</td></tr>
<tr><td>Mitsubishi Mining, Inc.</td></tr>
<tr><td>Mitsubishi Engines, Inc.</td></tr>
<tr><td>Kaibo Gikai[§]</td><td>32,000</td><td>1922-24</td></tr>
<tr><td>Japan Census Bureau</td><td>18,000</td><td>1922</td></tr>
<tr><td>Nippon Dennetsusen, Inc.</td><td>2,000</td><td>1930</td></tr>
<tr><td>Gonzo Ishii[**]</td><td>2,000</td><td>1930</td></tr>
<tr><td>Saito Fund[††]</td><td>39,100</td><td>1930</td></tr>
<tr><td>Kichizaemon Sumitomo</td><td>25,295</td><td>1932-34</td></tr>
<tr><td>Kichizaemon Sumitomo</td><td>1,750</td><td>1932</td></tr>
<tr><td>Mitsubishi Shipbuilding, Inc.</td><td>12,295</td><td>1932</td></tr>
<tr><td>Mitsubishi Shipbuilding, Inc.</td><td>7,800</td><td>1932</td></tr>
<tr><td>Kichizaemon Sumitomo</td><td>880</td><td>1933</td></tr>
<tr><td>Nippon Kako, Inc.</td><td>3,500</td><td>1935</td></tr>
<tr><td>Nippon Sanso, Inc.</td><td>3,020</td><td>1936</td></tr>
<tr><td>Sumitomo Mining and Metal, Inc.</td><td>17,000</td><td>1937</td></tr>
<tr><td>Ando Electrics, Inc.</td><td>900</td><td>1937</td></tr>
<tr><td>Nippon Metal Industries, Inc.</td><td>3,200</td><td>1937</td></tr>
<tr><td>Nippon Batteries, Inc.</td><td>4,080</td><td>1938</td></tr>
</table>

Source: Tohoku Teikoku Daigaku Kinzoku Zairyo Kenkyujo Yoran (1938), pp. 22-23

[*] Head of Sumitomo zaibatsu (business group)
[†] Head of Japan Special Steel, Inc. (current Daido Steel, Inc.), Chairman of Japan Steel Association
[‡] Head of Tokai Electrode, Inc. (current Tokai Carbon, Inc.)
[§] Imperial Maritime Defense Association (not-for-profit)
[**] Head of Ishii Construction, Inc.
[††] Nor-for-profit fund for academic research support, founded by private financier, Zenemon Saito.

Table C3. Riken's Capital Funding (yen)

	Emperor's donation	Government subsidy	Private firms
1917	100,000		3,081,700
1918	100,000		
1919	100,000	1,650,000	
1920	100,000		
1921	100,000		
1922	100,000		
1923	100,000	250,000	
1924	100,000	250,000	
1925	100,000	250,000	
1926	100,000	250,000	
1927		250,000	
1928		250,000	
1929		250,000	871,328
1930		250,000	
1931		250,000	
1932		250,000	
1933			
1934			
1935		900,000	
1936			
1937			
1938			
1939			
1940			
Total	1,000,000	5,050,000	3,953,028

Source: *Kenkyu 25 nen* (1942), p. 57.

Table C4. Riken's Largest Private Donors Around the Time of Founding

Year	1917	1918	1919	1920
Donor name	Hachiroemon Mitsui*	Hachiroemon Mitsui	Hachiroemon Mitsui	Hachiroemon Mitsui
Donation amount (yen)	500,000	500,000	500,000	500,000
Donor name	Koyata Iwasaki†	Koyata Iwasaki	Koyata Iwasaki	Koyata Iwasaki
Donation amount (yen)	500,000	500,000	500,000	500,000
Donor name	Rokuro Hara‡	Rokuro Hara	Rokuro Hara	Rokuro Hara
Donation amount (yen)	300,000	300,000	300,000	300,000
Donor name	Toranosuke Furukawa§	Toranosuke Furukawa	Toranosuke Furukawa	Toranosuke Furukawa
Donation amount (yen)	100,000	100,000	100,000	100,000
Donor name	Zensaburo Yasuda**	Zensaburo Yasuda	Zensaburo Yasuda	Zensaburo Yasuda
Donation amount (yen)	100,000	100,000	100,000	100,000
Donor name	Kihachiro Okura††	Kichizaemon Sumitomo‡‡	Kichizaemon Sumitomo	Kichizaemon Sumitomo
Donation amount (yen)	50,000	100,000	100,000	100,000
Donor name	Jokichi Takamine, Matasaku Shiobara§§	Fusanosuke Kuhara***	Fusanosuke Kuhara	Fusanosuke Kuhara
Donation amount (yen)	50,000	100,000	100,000	100,000
Donor name	Tadasaburo Yamamoto†††	Iwajiro Suzuki‡‡‡	Iwajiro Suzuki	Iwajiro Suzuki
Donation amount (yen)	50,000	75,000	75,000	75,000
Donor name		Kihachiro Okura	Kihachiro Okura	Kihachiro Okura
Donation amount (yen)		50,000	50,000	50,000
Donor name		Jokichi Takamine, Matasaku Shiobara	Jokichi Takamine, Matasaku Shiobara	Jokichi Takamine, Matasaku Shiobara
Donation amount (yen)		50,000	50,000	50,000
Donor name		Tadasaburo Yamamoto	Tadasaburo Yamamoto	Tadasaburo Yamamoto
Donation amount (yen)		50,000	50,000	50,000

Source: *Zaidan Hojin Rikagaku Kenkyujo Jigyo Hokoukshо*, No. 1 (1917), Appendix., p. 1; No. 2 (1918), Appendix., p. 1; No. 3 (1919), Appendix., p. 1; No. 4 (1920), Appendix., p. 1.

* Head of Mitsui zaibatsu (business group)
† Head of Mitsubishi zaibatsu
‡ Head of Industrial Bank of Japan, diversified business magnate
§ Head of Furukawa zaibatsu
** Head of Yasuda zaibatsu
†† Head of Okura zaibatsu
‡‡ Head of Sumitomo zaibatsu
§§ Co-founders and top executives of Sankyo Corporation
*** Head of Kuhara-Nissan business group
††† Shipping magnate
‡‡‡ Head of Suzuki Shoten / Ajinomoto business group

Table C5. Riken's Budget and Revenues from Patents

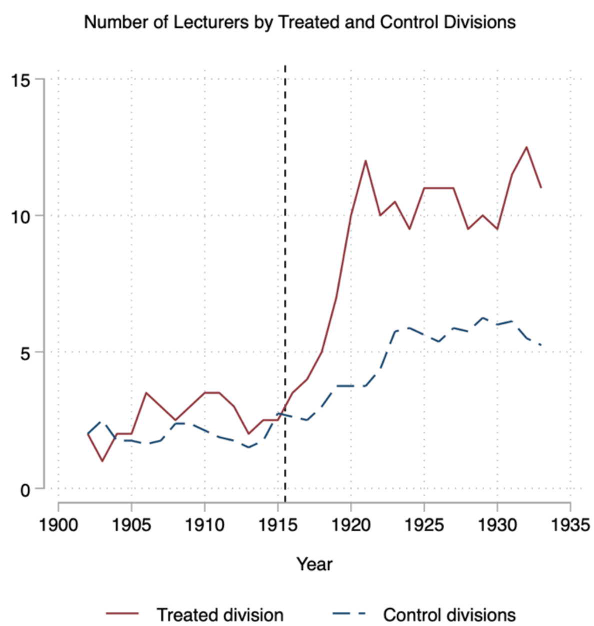
Yen

Year	Revenues	Expenses	Revenues from patents	Share of patent revenues
1917	53,384	21,775		
1918	136,254	63,225		
1919	210,680	109,909		
1920	275,838	162,453		
1921	305,930	247,940		
1922	271,123	319,415		
1923	942,857	900,507		
1924	884,945	885,619		
1925	987,212	986,538		
1926	1,180,660	1,045,655		
1927	659,541	621,370		
1928	855,164	689,839	30,237	0.035
1929	817,249	720,971	19,507	0.024
1930	596,866	673,413	10,351	0.017
1931	652,073	646,937	14,586	0.022
1932	669,020	684,244	43,154	0.065
1933	842,898	828,570	304,932	0.362
1934	839,780	822,920	107,220	0.128
1935	937,395	915,164	269,147	0.287
1936	2,150,519	1,240,301	746,581	0.347
1937	2,387,163	1,520,517	564,809	0.237
1938	3,074,088	1,889,024	1,676,667	0.545
1939	3,704,599	2,420,205	1,792,666	0.484

Source: *Kenkyu 25 nen* (1942), p. 61.

C.5. Appendix to Section VI, Case Examination of the Institute of Aeronautics

Figure C1. Institute of Aeronautics Effect: Time Trends in the Number of Lecturers Between Treated and Control Divisions



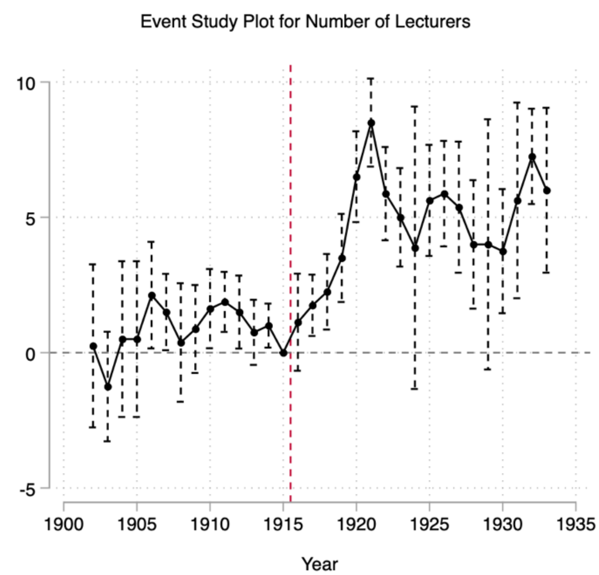
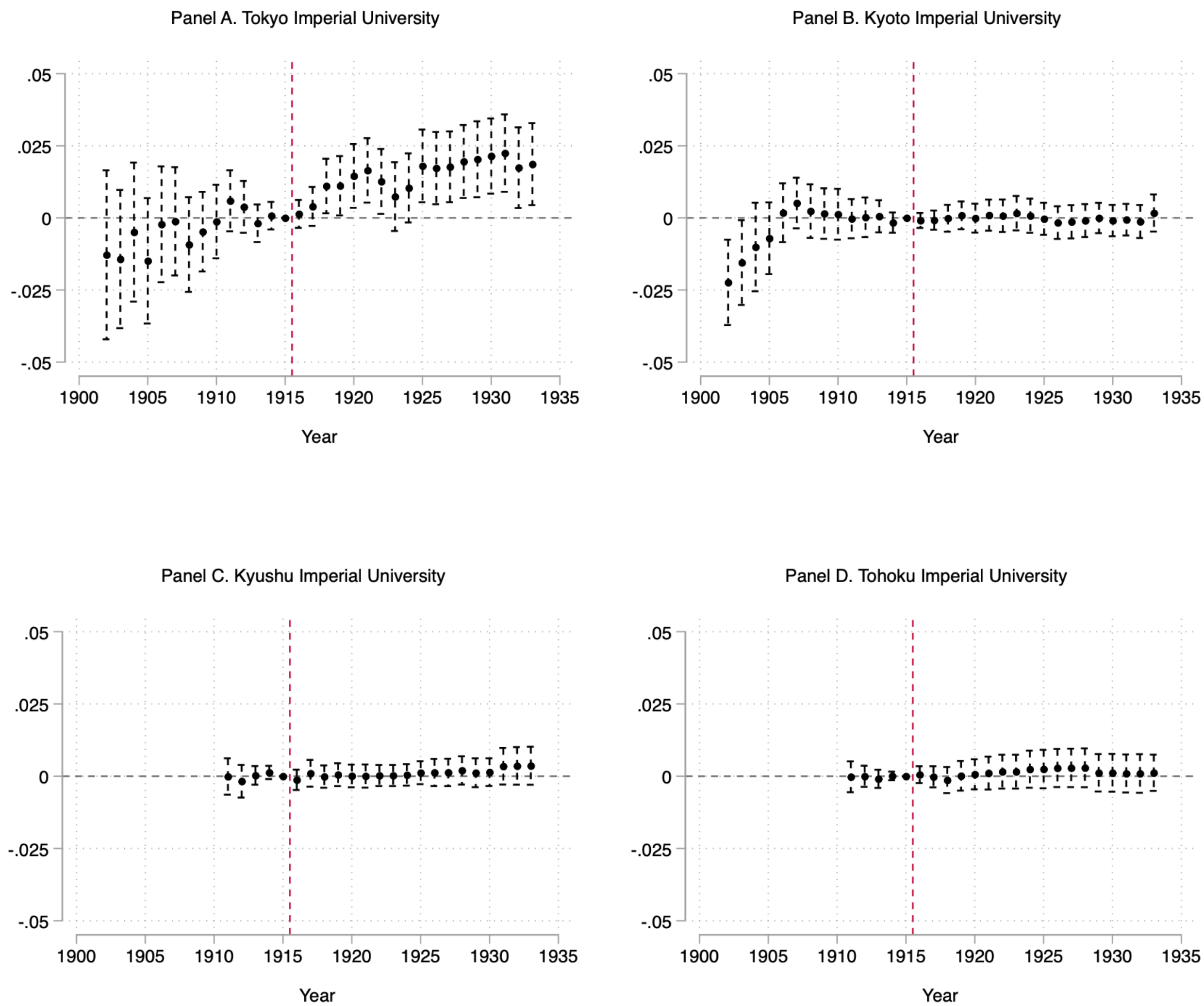


Figure C2 Institute of Aeronautics Effect, Event Study Plots: Placebo Tests



Note: Kyushu University Naval Architecture division establishment timing is controlled for. The growing trend in Kyoto Imperial University in the early 1900s is due to the expansion of its Mechanical Engineering faculty and it ends around 1905 anyway.

D. Structural Estimation Details

Here we summarize in more detail the structural estimation we employ in Section VII. In the first section, we provide the full description of the structural model. In the second and third sections, we discuss the estimation procedure and how to obtain the standard errors, respectively. In the fourth section, we describe the details on our simulation analyses. Finally, we describe the intuitive arguments on the identification of the parameters.

D.1. The Model

Time is discrete. Each graduate i has a finite decision horizon $a \in \{0, \dots, A\}$. At each age a, graduates choose among three occupation choices: working in academia (Imperial Universities' faculty) ($j = 1$), working in industry (the private sector) ($j = 2$), or working for the government or military ($j = 3$). Individuals get utility from both earnings $w_{ij}(a)$ and non-pecuniary utility (age-invariant utility $\beta_j X_i + \omega_{ij}$, where X_i are observable individual characteristics and ω_{ij} is an unobserved component, and age-variant utility $\rho\varepsilon_{ij}(a)$) if they choose occupation j. Their utility from earnings can be described by the CRRA utility function. They also have to incur a job switching cost $c_j(a)$ each time they move to occupation j from another occupation. Denote their occupation choice at age a by an indicator $d_{ij}(a)$ (equal to 1 if occupation j is chosen and 0 otherwise). Thus, the instantaneous utility for an individual at age a consisting of non-random flow of utility, $u_{ij}(a)$, and additively separable utility shocks, $\rho\varepsilon_{ij}(a)$, is written as:

$$U_{ij}(a) = \underbrace{\frac{[w_{ij}(a)]^{1-\gamma}}{1-\gamma} - c_j(a)[1 - d_{ij}(a-1)] + \beta_j X_i + \omega_{ij}}_{u_{ij}(a)} + \rho\varepsilon_{ij}(a),$$

for each occupation j, where we assume that $\varepsilon_{ij}(a)$ is independent and identically distributed across individuals and over time and follows the Type I extreme value distribution $G(\varepsilon)$, while ρ is a scaling parameter. Since utility is additive invariant, we normalize the non-pecuniary utility in industry to 0, so $\beta_j X_i + \omega_{ij}$ represents the value relative to the private sector. The (logged) wage process for individual i in sector j is given by:

$$\ln w_{ij}(a) = b_{j1} + b_{j2}a + b_{j3}a^2 + b_{j4}t + \nu_{ij} + \sigma_j \varsigma_{ij}(a),$$

where ν_{ij} is an individual-specific earning potential in sector j (with the mean of 0) and $\{\varsigma_{ij}(a)\}_{j=1}^{3}$ are ex post idiosyncratic earning shocks that depend on age a and follow joint standard normal distribution $N(0, I)$ independentl. We assume that individuals cannot observe these idiosyncratic shocks at the time occupation choices are made in each period. We also assume that the job switching cost function takes the following log-linear form and is quadratic in terms of individual age:

$$\ln c_j(a) = c_{j1} + c_{j2}a + c_{j3}a^2.$$

This allows for individuals of different ages to face different frictions (e.g., the cost of changing a job can be higher for older individuals).

At each age a, graduates maximize the expected present value of remaining lifetime utility. Defining the individual state space by $s_i(a) = \{a,\ \{d_{ij}(a-1),\ \omega_{ij},\ \nu_{ij}\}_{j=1}^{3}\}$, we can write the value function as the conditional expectation of the flows of current and future utility, which also satisfies:

$$V_i\big(s_i(a)\big) = \max_{d_{ij}(a)} \quad E\left[u_{ij}(a) + \rho\varepsilon_{ij}(a) + \delta \int V_i\big(s_i(a+1)\big) dG(\varepsilon) \middle| s_i(a)\right],$$

where δ is a discount factor and the integral refers to integration over $\varepsilon_{ij}(a)$. The expectation operator is taken over the distributions of current $\varsigma_{ij}(a)$ and future $\varsigma_{ij}(a)$ conditional on the individual state space $s_i(a)$. Following the tradition of dynamic discrete choice models, we can have a closed form of conditional choice probability. Define $v_i\big(s_i(a)\big) = \int V_i\big(s_i(a)\big) dG(\varepsilon)$ to be the integrated value function. Then, one can also define the choice-specific value function:

$$v_{ij}\big(s_i(a)\big) = E\big[u_{ij}(a) + \delta v_i\big(s_i(a+1)\big) \big| s_i(a), d_{ij}(a) = 1\big],$$

as the value of $v_i\big(s_i(a)\big)$ conditional on choosing occupation j net of the utility shock. Using these notations, we can rewrite the individual optimization problem as:

$$v_i\big(s_i(a)\big) = \max_{d_{ij}(a)} \quad v_{ij}\big(s_i(a)\big) + \rho\varepsilon_{ij}(a),$$

The distributional assumption of $\varepsilon_{ij}(a)$ implies that the conditional occupation choice probability at age a can be written as the following logit form (Rust, 1987):

$$P\big[d_{ij}(a) = 1 \big| s_i(a)\big] = \frac{\exp\big[v_{ij}\big(s_i(a)\big)/\rho\big]}{\sum_k \exp\big[v_{ik}\big(s_i(a)\big)/\rho\big]}.$$

Therefore, given individual state variables (age and previous period occupation choice), unobserved non-pecuniary gains and earning potential, and parameter values, we can derive the joint distribution of earnings and occupation choice from the model.

To derive the treatment effect of the establishment of the Institute of Aeronautics in our structural estimation, we assume that the establishment of the Institute of Aeronautics was an unexpected event, and that each individual calculates the continuation value without taking into account the future non-pecuniary utility from working in academia up to 1915. That is, we set the parameter for the non-pecuniary utility gain coming from the Institute of Aeronautics to zero when deriving the value function up to 1915, and we treat it as the estimation parameter afterward. We allow this unexpected change in value function only for graduates from Naval Architecture and Mechanical Engineering divisions as in Section VI.

D.2. EM Algorithm

This section describes the EM algorithm we use in our estimation. Denote the set of parameters that is invariant across types by θ, the set of unobserved heterogeneity by λ_q, and the proportion of the q-th type in the population by π_q. Then, the algorithm is given as follows.

1. Start with the initial guess of $\theta^{(1)}$, $\lambda_q^{(1)}$, and $\pi_q^{(1)}$.
2. E-step: Given $\theta^{(n)}$, $\lambda_q^{(n)}$, and $\pi_q^{(n)}$ for each iteration $n = 1, 2, \ldots$, generate the posterior probability of being type q by:

$$\pi_{iq}^{(n)} = \frac{\left\{\prod_{a=1}^{A} P\left[d_{ij}(a) = 1 \middle| s_i(a), \theta^{(n)}, \lambda_q^{(n)}\right] f\left[w_{ij}(a) \middle| s_i(a), \theta^{(n)}, \lambda_q^{(n)}\right]\right\} \pi_q^{(n)}}{\sum_k \left\{\prod_{a=1}^{A} P\left[d_{ij}(a) = 1 \middle| s_i(a), \theta^{(n)}, \lambda_k^{(n)}\right] f\left[w_{ij}(a) \middle| s_i(a), \theta^{(n)}, \lambda_k^{(n)}\right]\right\} \pi_k^{(n)}}.$$

3. M-step: For $\pi_{iq}^{(n)}$ fixed, obtain new parameter estimates $\theta^{(n+1)}$, $\lambda_q^{(n+1)}$, and $\pi_q^{(n+1)}$ by maximizing the finite mixture of the likelihood:

$$L(\theta^{(n+1)}) = \prod_{i=1}^{N} \sum_{q=1}^{Q} \pi_{iq} \left\{ \prod_{a=1}^{A} P\left[d_{ij}(a) = 1 \middle| s_i(a), \theta^{(n+1)}, \lambda_q^{(n+1)}\right] f\left[w_{ij}(a) \middle| s_i(a), \theta^{(n+1)}, \lambda_q^{(n+1)}\right] \right\},$$

4. Iterate on steps 2-3 until convergence in $\theta^{(n+1)}$, $\lambda_q^{(n+1)}$, and $\pi_q^{(n+1)}$.

We need the initial guess of the model parameters to operationalize this procedure. We follow Traiberman (2019) and first set the initial guess of $\theta^{(1)}$ to the estimates from the single-type version of the model. For the unobserved heterogeneity parameters, we set the initial values to a small perturbation around the results for a single-type version of the model, and for the distribution of unobserved types, we start from the equal proportion (25% for each type).

D.3. Parametric Bootstrap Standard Errors

This section describes the details on our parametric bootstrap procedure used to obtain standard errors in the structural estimation. For finite mixture models, the asymptotic variance is likely to be a poor approximation (McLachlan and Peel, 2004; Arcidiacono et al., 2024). We rely on a parametric bootstrap procedure instead of non-parametric one since the latter is unstable when applied to the EM algorithm (Beffy at al., 2012). We create 100 bootstrap replications, and we take the following steps in each replication.

1. Draw the unobserved type q from the estimated population distribution of types, $\hat{\pi}$, for each sampled individual and assign the fixed type to each one.
2. Given the individual characteristics, including their graduation cohort, academic status (honor student or top in third year), and unobserved type, calculate the value functions and simulate their earnings and

occupation choices until period $T = 35$, the longest panel length in the sample. Repeat this forward simulation on the cross-section of N sampled individuals (see also AX4).

3. For each bootstrapped sample generated from this forward simulation, estimate the structural parameters as in the main estimation. For these estimations, we use the parameters estimated in the main sample as the initial values.

Repeat steps 1-4 100 times. Once we have obtained the parameter estimates for all bootstrap replications, we estimate the standard errors of the parameters as the standard deviations of the estimates across bootstrap replications.

D.4. Model Fit and Counterfactual Simulations

This section details the steps we take for the model fit and counterfactual simulations. These steps are similar to the steps we take in the parametric bootstrap procedure. More specifically, we take the following steps to produce simulated data consistent with the estimated parameters and counterfactual parameters.

1. Draw the unobserved type q from the estimated population distribution of types, $\hat{\pi}$, for each sampled individual and assign the fixed type to each one.
2. Given the individual characteristics, including their graduation cohort, academic status (honor student or top in third year), and unobserved type, calculate the value function for each individual using either the estimated parameters (when assessing the model fit) or the counterfactual parameters (when assessing the counterfactual scenarios).
3. Simulate their earnings and occupation choices until period $T = 35$, the longest panel length in the sample, using the derived value functions in step 2. Repeat this forward simulation on the cross-section of N individuals in our sample 10 times.

This process yields a panel data of simulated earnings and occupation choices that structurally resembles the data we use in estimation or that would be consistent with counterfactual scenarios.

D.5. Wage Premium in the Private Sector

This section explains how we calculate the wage premium in the private sector described in the main text. To define the wage premium, we calculate how much the private sector could decrease the wage if the academia would not offer any non-pecuniary payoffs. More specifically, we take the following steps:

1. Using the estimated parameters, calculate the predicted conditional probability that each unobserved type q chooses to work in the private sector.
2. Consider a counterfactual where the non-pecuniary payoffs in academia are set to zero.
3. Find the level of the constant term in the wage function for the private sector so that the counterfactual probability to work in the private sector becomes the same as the predicted probability calculated in step 1.

4. Based on the difference in the parameters between original and counterfactual settings, calculate how much wage adjustment is required to keep the same fraction of individuals in the private sector.

The calculated wage premium basically represents how much wage premium the private sector needed to provide to attract the same fraction of top graduates as it actually did because of the existence of the non-pecuniary payoffs in academia.

D.6. Intuition behind Identification

Although it is difficult to make a straightforward argument for identification in a complex dynamic structural model without the analytical solution, it is also important for us to understand the intuition on how the parameters in the model can be identified using the variations in our data. The parameters in the model can be categorized into three groups; (1) those in the wage function, (2) those in the switching cost function, and (3) those related to non-pecuniary preferences.

The parameters in the wage functions are identified in the similar way to Mincer regression in Table 1, but with one modification. While Mincer regression does not take the self-selection issue into account, the structural model version reflects the fact that individuals tend to choose a sector with higher expected earnings. However, since we make assumption that the earning shocks are realized ex post after individuals choose occupation, the biases in the coefficient estimates caused by self-selection based on the unobserved earning shocks are not the issues in this estimation.

Second, and most importantly, the identification between the switching costs and non-pecuniary payoffs are key in our structural estimation. Both factors influence the variations in individual occupation choices that cannot be explained by the variations in earnings. For example, if some individual chooses to work in academia consistently despite its lower earnings compared to other sectors, it is likely that either (s)he derives higher non-pecuniary utility from academia or moving to other sectors is costly due to high switching costs. Even though these two factors are unobservable and it is generally difficult to distinguish one from the other, some variations in individual occupation choices are informative for the identification of these parameters. First, to separate persistence in occupation choices due to non-pecuniary preference as opposed to persistence due to switching costs, we can see whether individuals tend to "return" to their original sectors after moving to other sectors. For example, if persistence in the academic sector is mostly due to higher non-pecuniary preference for academia rather than the existence of switching costs, then we would expect that even if individuals move to other sectors for a short period, once they get a positive shock in the academic sector (or a negative shock wherever they are), they will tend to come back to the academic sector. On the other hand, if persistence in the academic sector is mostly due to switching costs (i.e., individuals somehow choose to work in the academic sector at some point and then are stuck in the same sector due to high switching costs), then once they switch, the move tends to be permanent since the "return" to academia incurs additional higher mobility costs and rational forward-looking agents do not move to other sectors just for a short period if coming back to academia in the future is desirable for them. Second, while our assumption imposes that switching costs are a function of individual age, non-pecuniary payoffs are not systematically related to individual age (although they are still age-variant due to independent utility shock $\varepsilon_{ij}(a)$). While the switching costs can be expected to be increasing in individual age (e.g., opportunity costs of learning), individual preferences for specific sectors are relatively stable, so the assumption that only switching costs depend on individual age is not unreasonable. With this specific assumption, the age-dependence of individual occupation choices is also informative for the identification of coefficients in the switching cost function.

Finally, for the identification of the scaling parameter, ρ, the transition rates to other sectors help to pin down the parameter value. More specifically, as we have higher value of ρ, the mobility between sectors becomes less responsive to earning differentials. Therefore, the dependence of individual mobility on sector-specific earnings is key to the identification of the scaling parameter (it is identified together with the levels of the switching costs and non-pecuniary payoffs).

D.7. Reduced Form Validation

We also conducted a "sanity check" of the outcomes of our structural estimation using reduced form specifications. Specifically, we first estimated Mincer-type earning regression as in Table 1, with individual, times employment sector fixed effects, using the sample of top graduates and starting from the 1887 graduation cohort from which we have designation as honor students. Next, we separated the individuals into those employed in academia (Imperial Universities' core faculty) at some point in their careers and those who were never employed in academia. Finally, we divided those employed in academia into "high" (above the median) and "low" (below the median) earners based on the estimated individual, times employment sector (academia) fixed effects. We then calculated the summary statistics on average real earnings as well as average individual characteristics X_i used in the structural estimations above for each of the above three subsamples. Table 3 presents those statistics.

The bottom two rows in Table D1 show the split among the three subsamples between earlier graduation cohorts (those who graduated before 1900) and later graduation cohorts (those who graduated in 1900-1918; the results are qualitatively similar for other reasonable cutoffs). About 69 percent of earlier-cohort graduates (76 out of 110) had never been employed in academia, but this fraction is somewhat lower, at about 66 percent (124 out of 187) for later-cohort graduates, in line with the general trend toward higher share of top graduates choosing careers in academia observed in Figure 3 above. Among those with employment history in academia, top graduates with earnings above the median earn on average about 72 percent more than top graduates with earnings below the median overall, and 66 percent more if employed in Imperial Universities.

The most important finding is that those with the history of employment in academia are divided very unequally between high and low earners across earlier and later graduation cohorts. High earners are almost entirely concentrated among those who graduated prior to 1900, while two thirds of those who graduated in

1900-1918 are low earners. Furthermore, as can be seen from the top rows in Table 3, “low earners” among top graduates in academia were significantly more likely to be honor students and also to have graduated from high-tech divisions (defined as electric engineering and applied chemistry, the two divisions most closely related to the technologies powering the Second Industrial Revolution). Thus, we find no evidence that below-the-median earners among the top graduates who chose to be employed in academia had any disadvantage in terms of ability (academic achievement) or fit to growing high-tech industries of the time; if anything, the opposite was true. This is consistent with the findings from structural estimations that although monetary compensation may have been important in choosing careers in academia early on, increasing non-pecuniary motivation had a much bigger role in later cohorts and among top early achievers.

Table D1. Validation from Raw Data

	Academia: High Earners	Academia: Low Earners	Non-Academia
Education records:			
Honor student (%)	59.2	72.1	45.7
Top after second year (%)	79.6	76.7	64.7
Top at time of graduation (%)	100.0	100.0	100.0
High-tech divisions (%)	20.4	27.9	23.5
Outcomes:			
Imperial University faculty (%)	100.0	100.0	0.0
Real earnings (yen)	5,582.4	3,238.3	5,681.0
Imperial University real earnings (yen)	5,222.8	3,140.6	-
Observations:	54	43	200
Cohorts graduated before 1900	33	1	76
Cohorts graduated in 1900-1918	21	42	124

Note: “Academia: High Earners” are Imperial University engineering faculty with residual earnings above the median. “Academia: Low Earners” are Imperial University engineering faculty with residual earnings at or below the median. “High-tech divisions” are electric engineering and applied chemistry divisions in the College of Engineering. Real earnings are nominal earnings, deflated by the consumer price index.

E. Career paths before joining academia

Using long-term career data on engineering graduates who become engineering faculty, we can examine various paths the led them to join the Imperial University faculty. Table E1 presents the distribution of previous employment sectors for all engineering faculty at Tokyo Imperial University and separately for core and non-core faculty, with the breakdown of each category into those hired in 1896-1907 versus in 1908-1920.[1]

Table E1. Sectors of Employment Just Before Joining Engineering Faculty

Panel A. All Faculty

	Sector of Previous Job Prior to Joining Faculty						
Variables	Private	Public	Military	Research	Direct	Unknown	Total
All hires	26 (15.29)	45 (26.47)	23 (13.53)	22 (12.94)	45 (26.47)	9 (5.29)	170 (100.00)
Hired in 1896-1907	13 (16.46)	16 (20.25)	7 (8.86)	9 (11.39)	30 (37.97)	4 (5.06)	79 (100.00)
Hired in 1908-1920	13 (14.29)	29 (31.87)	16 (17.58)	13 (14.29)	15 (16.48)	5 (5.49)	91 (100.00)

Panel B. Core Faculty

	Sector of Previous Job Prior to Joining Faculty						
Variables	Private	Public	Military	Research	Direct	Unknown	Total
All hires	14 (14.14)	20 (20.20)	6 (6.06)	15 (15.15)	39 (39.39)	5 (5.05)	99 (100.00)
Hired in 1896-1907	7 (13.46)	8 (15.38)	3 (5.77)	6 (11.54)	25 (48.08)	3 (5.77)	52 (100.00)
Hired in 1908-1920	7 (14.89)	12 (25.53)	3 (6.38)	9 (19.15)	14 (29.79)	2 (4.26)	47 (100.00)

Panel C. Non-core Faculty

	Sector of Previous Job Prior to Joining Faculty						
Variables	Private	Public	Military	Research	Direct	Unknown	Total
All hires	12 (16.90)	25 (35.21)	17 (23.94)	7 (9.86)	6 (8.45)	4 (5.63)	71 (100.00)
Hired in 1896-1907	6 (22.22	8 (29.63)	4 (14.81)	3 (11.11)	5 (18.52)	1 (3.70)	27 (100.00)
Hired in 1908-1920	6 (13.64)	17 (38.64)	13 (29.55)	4 (9.09)	1 (2.27)	3 (6.82)	44 (100.00)

Note: Panel A represents the number and share (in parentheses) of newly hired engineering faculty by sectors of their immediate previous employment. Panel B and C show the same statistics for core and non-core faculty separately. Here, faculty are categorized as core faculty if they became core faculty at some point in our sample periods. "Direct" refers to faculty who were hired within the first two years after graduation and did not have job records in other sectors prior to becoming faculty.

For the purpose of this estimation, we limited the sample to graduates who became engineering faculty at some point and coded the sector of employment where the graduate worked right before joining engineering faculty

[1] The job histories for those hired in 1895 and earlier are sparse because our graduates panel starts in 1890 and many job observations are missing in early years. We therefore exclude them from this analysis. We also exclude faculty hired after 1920 because we do not have the data on job histories of post-1920 graduates who are an increasing fraction of engineering faculty after 1920.

as private, public, military, or academia/research, while allowing gaps of up to five years between the last pre-faculty employment and the year the graduate was employed by the university. (That is, if the graduate worked in the private sector in year $t-1$, where year t is the year he joined the faculty, his last sector of employment would be private, and the same if employment information was missing in year $t-1$ but he worked in the private sector in year $t-2$, and so on.) If there was no employment information for any of the five years prior to joining the engineering faculty, we coded the previous sector of employment as missing. Since some graduates joined the ranks of faculty immediately or soon after graduation, we coded such graduates in a separate category (labeled "Direct" in Table E1) if they became faculty within two years after graduation and there was no employment information in other sectors during the (at most two) years that elapsed between their graduation year and the year they joined the faculty.

[Table E1 around here]

First, looking at all hires, almost 39.4 percent of core faculty were in the "Direct" category, that is, recruited right after or within four years from graduation (allowing also for graduate school), but only 8.5 percent of non-core faculty came from this category. This reflects the hiring policy where top graduates were offered (almost) immediate "tenure-track" positions upon graduation, while part-time lecturers were mostly brought for their practical expertise. Second, looking at changes over time, the fraction of faculty recruited directly from recent graduates goes down from the 1896-1907 period to the 1908-1920 period, most drastically for non-core faculty but also by about 40 percent for core faculty. In contrast, the fraction of faculty hired from other sectors grows, except for the share hired from the private sector which basically remained flat. This is consistent with academia becoming more attractive to mid-career professional over time, especially those who had previously worked in the public sector.

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