Talent Allocation into University Faculty:

Utilizing Data on Educated Engineers During Japan's Modernization

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Abstract

Higher technical education institutions play an important role in training industrial scientists and engineers and generating new technologies. How well they can perform this role, however, depends on whether they can recruit and retain talented faculty. We utilize the data on the universe of all university-educated engineers during the first 40 plus years of Japan's transition to modernity to examine selection into academia. Strikingly, while just about 10 percent of all graduates worked as faculty at Imperial Universities in at least one year during our sample, the same share was 40 percent among top-ranked graduates. Thus, academia disproportionately attracted top talent despite strong competition from the private sector and government. Structurally estimating a simple dynamic model of occupational choice, we find that later graduates were more likely than earlier graduates to place high value on non-pecuniary benefits offered by academia, and this compositional change, which we trace to institution-building measures and increased provision of complementary assets, helped academia compete for talent. We also find that graduates whose occupational choice was influenced by high taste for academia stood out among their peers in terms of academic achievement long before graduation, suggesting that top-talent students may endogenously develop preferences for academia.

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I. Introduction

The role of human capital in modern development, both of pioneering and catch-up nature, is well established (Goldin, 2001; Galor and Moav, 2006; Becker, Hornung, and Woessmann, 2011). While much of the literature has focused on basic education (Becker et al., 2011; Barro and Lee, 2015; Krueger and Lindahl, 2001; Godo and Hayami, 2002), in the seminal article on endogenous growth, Romer (1990) talks about "a college-educated engineer" as the driver of such growth. Recent research has demonstrated the importance of the upper tail of educated human capital, especially engineers (e.g., Squicciarini and Voigtländer, 2015; Maloney and Caicedo, 2022; Yamaguchi, Braguinsky, and Nakajima, 2021). Indeed, as the emergence of electricity, electric motors, batch methods in chemicals and other technological advances in the late 19th-early 20th century ushered in the complementarity between physical and skilled human capital for the first time (e.g., Goldin and Katz, 1998), educated engineering human capital became indispensable for successful industrial growth (e.g., Maloney and Caicedo, 2022) and for the success of innovative firms driving such growth (e.g., Braguinsky, Ohyama, Okazaki, and Syverson, 2021).

Top educated engineers need to be produced in institutions of higher technical education. As pointed out by Nelson and Rosenberg (1993), such institutions play an extremely important role in technical advance, "not only as places where industrial scientists and engineers are trained, but as the source of research findings and techniques of considerable relevance to technical advance in industry." This role has so far been examined mostly at the institutional level, focusing on various forms of policy interventions and their impact (Becker et al., 2011; Hvide and Jones, 2018; Valero and Van Reenen, 2019) and/or using geographical location to measure the impact on fostering and disseminating innovation (Jaffe, 1989; Toivanen and Väänänen, 2016; Valero and Van Reenen, 2019; Maloney and Caicedo, 2022).

What largely remains a "black box" in all these studies, however, is how university recruits and retains talent in the first place. While government policies and other public interventions can create institutions of higher education and incentives, how much talent such institutions produce and how much universities themselves contribute to research findings relevant "to technical advance in industry" critically depends on the university attracting and retaining high-level human capital in faculty positions. This may be especially important for earlier stages of development where top-notch educated talent is particularly scarce, so that directing it toward academia involves especially large individual and social opportunity costs, although the problem is definitely more general, as the recent case of Uber Technologies poaching 40 top researchers from the Carnegie Mellon University robotics department and plunging it into "crisis" clearly demonstrates (Ramsey and MacMillan, 2015). In this paper, we aim at opening this black box of talent selection into and its retainment by a university. A companion paper will examine how top-talented faculty helped to produce the next generation of top talent.

Past literature has uncovered that preferences for non-pecuniary returns ("the taste for science") play a big role in the decisions by highly educated/talented individuals to choose careers in academia (Stern, 2004; Roach and Sauermann, 2010; Agarwal and Ohyama, 2013). The general sense is that "scientists pay to be scientists" (Stern, 2004). However, as also discussed in the literature, individual ability and preferences for non-pecuniary returns in academia may be positively correlated. Since direct measures of both are generally not available to researchers, it remains hard to distinguish between the two empirically. One exception is a recent study by Roach and Sauermann (2023) who utilize the data on both ability and preferences prior to entry into the job market and show, although in a somewhat different context, that PhDs accept approximately 17% less pay to work for a startup as opposed to an established firm. It is also worth mentioning

that all the above studies employ the data on doctorate degree recipients who, by their nature, may have higher intrinsic preferences for academia (and non-pecuniary returns) than other, similarly talented individuals who choose not to pursue PhD degrees. Hence, overall, there is still a dearth of empirical studies that would address the issues of selection into academia/university faculty using large data sets on top-notch talent.

In this paper, we utilize our own, hand-constructed data set to examine who selects into academic careers ("engineering faculty") from among the universe of all graduates of the Tokyo Imperial University Engineering Department during the emergence and growth of the modern higher technical education system in Japan, starting from its inception and until the 1920 graduation cohort. The Engineering Department of Tokyo Imperial University was Japan's first institution of higher technical education (the first cohort graduated in 1879 even before it was incorporated into the Imperial University) and it remained the only place to obtain university-level engineering education in Japan for more than 20 years, until 1901 when the first cohort graduated from the newly established Kyoto Imperial University. Even by 1920, graduates of this department accounted for about 70 percent of all university-educated engineers in Japan.

Since a bachelor's degree qualified its holder for an academic job at the time (Amano, 2004, Vol.1, p. 199), our historical context allows us to circumvent the pre-selection into PhD programs. At the same time, graduates from the Imperial University were the educational elite, comparable to doctorate recipients of today, just without the pre-disposition for academic jobs.[1]

Our data (described in the next section with more details in Appendix B) come from the large, hand-constructed database developed together with Shotaro Yamaguchi and covering the

[1] Japan did confer doctorate degrees during the period of our studies, but those were predominantly awarded based not on graduate education, but on peers' recommendation or upon submitting doctoral dissertations, which typically happened mid-career (Nakayama, 1978; Amano, 2004, Vol. 1).

universe of all recipients of Bachelor's Degrees in science and engineering from Imperial Universities in Japan, starting with the inception in the late 1870s and until the 1920 graduation cohorts, with careers observed annually, potentially until 1940, and matched also with patenting data. From this database, we extracted all the graduates of the Tokyo Imperial University Engineering Department and hand-matched them with our own dataset comprised of all faculty members who taught at the same department as well as in other Imperial Universities established prior to 1920, in at least one year until 1939.

Our first stark finding is that the engineering faculty was comprised of a disproportionately high share of top-notch talent. Specifically, the share of top-ranked graduates who chose to be full-time employed in academia at least once during their careers was four times higher than the same share among all graduates. Moreover, while the overall share of graduates who became academic faculty exhibited a pronounced decline over time, as the growth in the availability of academic jobs was outpaced by the growing number of graduates, the share of top graduates who chose academia remained stable or even increased during our sample. As a result, 50% of all engineering faculty at Tokyo Imperial University were comprised of top-ranked graduates from the same engineering department, and this share rises to 80% if we include those who graduated second and third in their cohorts.

The success in employing top talent in academia was no minor accomplishment, given strong competition from the private sector, government agencies, and the military. Motivated by this finding, we set out on a journey to examine the factors that made this possible. Guided by the previous literature, we examine the role played by both pecuniary compensation and non-pecuniary preferences, using a separate hand-constructed data set on earnings of top-ranked graduates, combined with detailed information about their occupational choices at each point in

time. The nature of the historical data we use preclude us from having direct information about non-pecuniary preferences. We thus develop a model in the spirit of Keane and Wolpin (1997) to structurally estimate the dynamic model of occupational choice to quantitively fit the observed data patterns. The structural estimations indicate that non-pecuniary motivation did indeed play an important role in top talent choosing academic careers although this role was heterogenous across different individual types. The type with the highest preference for academia actually had employment in the public sector/military as their second-preferred choice, while the estimated size of their non-pecuniary benefits in academia (relative to industry) was as large as their average annual income.[2] Counterfactual simulations where we shut down the non-pecuniary benefits indicate that the university may have lost up to 50% of top graduates who actually joined academia in such a case, having to replace them will less talented individuals. Leveraging unique data that allow us to observe ability (academic achievement) at various stages of education (starting from high school) we also find that conditional on being a top graduate, the individual was more likely to develop preferences for academia if he had been a top student even before graduating and entering the labor market. Thus, ability and taste for academia are indeed correlated; moreover, it looks like preferences for academia emerge endogenously as people realize they are good at it.

We also find that the University produced relatively more graduates with high non-pecuniary preferences for academic jobs among later cohorts than in earlier cohorts. This appears to have resulted from targeted institution-building aimed at enhancing non-salary benefits as the university found itself competing against higher salaries in the private sector. Indeed, the historical, long-term nature of the data allow us to observe what looks like an endogenous shift in the share of top-talented individuals with preferences for academia as academia itself was built from scratch.

[2] This is also consistent with Traiberman (2019), who estimates the size of non-pecuniary benefits to be about 1-2 years of average annual income.

One consequence of selection of top talent into engineering faculty was that such faculty tended to possess high innovative potential, especially in certain divisions closely related to high-tech industries of that era. In response, the University encouraged academia-industry collaboration as well as created and provided complementary assets, such as the system of research sabbaticals at top universities abroad and affiliated research institutes. This appears to have helped Japan's academia at the time to become a hot-bed for generating industry-related technologies and their commercialization (cf. Nelson and Rosenberg, 1993).

We believe that this may be the first paper to examine the selection into academic jobs using the universe of all the graduates, not just those who pursued doctorate degrees after graduation. Furthermore, the nature of Japan at the time as a developing nation which had just set out on the task of building a modern higher technical education system makes our study particularly valuable for examining the role of talent allocation into university-level science and engineering in development generally—a vastly understudied subject despite its importance.

II. Data Development

As mentioned, the data utilized for this paper is part of the on-going large-scale data-construction project joint with Shotaro Yamaguchi and involving also a collaborating team in Japan. The overarching goal is to create, verify, and eventually put in the public domain the database on all individuals who received their Bachelor's Degrees in Science and Engineering from Japan's Imperial Universities from the inception of the first one of them in 1877 and until the 1920 graduation cohorts, which will combine the data on their education, annually updated post-graduation employment and innovative activity as measured by patents.[3]

[3] While the 1920 end-point for adding graduates to our sample is somewhat arbitrary, we were drive by the fact that career data of graduates would be interrupted by the start of World War II which devastated the Japanese economy and its society. We wanted to have at least 20 years of potential career observations on our sample, and we would not be able to have that for those who graduated in 1921 and later.

The work on this large database is still ongoing. So far, the team has been able to assemble the list of all Bachelor Degrees' recipients mentioned above, match them to the high schools they graduated from, extract the information about employment in each year after graduation from the annual surveys taken by the Alumni Association of Imperial Universities. We then utilized the data on names, addresses and workplaces to hand-match them to domestic patenting data from Japan Patent Office and to global patents obtained from Google patent data, constructing, for the first time, the crosswalk between university science and engineering graduates' data and patents data in Japan. More details about the work that has been already completed are described in two working papers, Yamaguchi, Braguinsky, and Nakajima (2021) and Yamaguchi, Inoue, Nakajima, Okazaki, Saito, and Braguinsky (2022), as well as in Appendix B to this paper.

This paper, which also serves as an illustration of potential usefulness of the data construction project in the previous paragraph, makes use of the following components.

First, from the large database above, we extracted the data on the graduates of Tokyo Imperial University Engineering Department and matched those to our own hand-constructed data covering all the engineering faculty in the same department as well as engineering departments at other Imperial Universities. The primary data source is the annually published Imperial University Calendars (such as *Tokyo Teikoku Daigaku Ichiran*, also called *Tokyo Teikoku Daigaku Yoran* in some years) available in open access through the National Diet Library Digital Collections (https://dl.ndl.go.jp/en/). These Calendars contain lists of faculty members (names, job titles such as Professor, Assistant Professor, Lecturer, etc., and courses taught in any given year) as well as the list of required and elective courses for students to take. Information is available on years faculty members traveled for research or study abroad—such travel was critically important for Japanese engineers at that time.

The data on Tokyo Imperial University graduates until the 1918 graduation cohorts provide us with a rare opportunity to have direct measures of students' academic achievement before they entered the job market. Up until 1918, Tokyo Imperial University rules stipulated that students were listed in the University Calendars 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 (e.g., the Engineering Department rule in *Tokyo Teikoku Daigaku Ichiran*, 1907, p. 198). Since the graduates were listed in the University Calendars separately by graduation year, month and division (such as Civil Engineering, Mechanical Engineering, etc.), the measure is division-cohort-specific, that is, it reflects how well the student performed in tests and diploma relative to his peers in the same division throughout his study.[4][5] Furthermore, over 80 percent of students entered the university after graduating from one of the (old-system) high schools which served as gateways to the Imperial University. The same rule of listing graduates in the order of their test scores was applied in high schools as well, providing us with the measure of academic achievement relative to peers right before entering the university.

As the primary focus of this paper is ability sorting into faculty jobs, we additionally digitized earnings data on top graduates. Specifically, Japan's annual *Who is Who* (*Nihon Shinshiroku*) started reporting income taxes paid by those listed in it from 1902. We hand-matched top-ranked Engineering Department graduates in our data with the names and addresses in *Who is Who* and then used the information about income tax schedules in any given year reported by Japan's Tax Bureau (*Shuzeikyoku Tokei Nemposho*, 1896-1939) to back out top graduates'

[4] Listing of students and graduates in the order of *Sekiji* was discontinued and replaced by alphabetical ordering in 1919. Hence, our selection analysis drops the graduates from the final two cohorts.

[5] We use male pronouns in this paper because women were not admitted to Tokyo University until 1946, so that all the graduates and all the faculty in our data are males and more than 99% of graduates are ethnic Japanese.

incomes. The total number of engineering department graduates who graduated at the top of their division-cohorts in our sample is 353; among those, we were able to match 263 individuals to *Who is Who,* giving us 2,183 non-missing income tax (and income) observations between years 1902-1922.[6] We utilize these income data when examining factors affecting which graduates chose academic careers in our estimations below.

III. Brief Historical Background: Tokyo Imperial University Engineering Department

The Meiji Restoration of 1868 marks the start of Japan's rapid catch-up development (Dyer, 1904; Landes, 1998). At the time, the country completely lacked engineering and other forms of higher science and technical education, which had to be built from scratch by initially relying entirely on invited foreign teachers (Gospel, 1991). In 1873, the new Meiji government signed a contract with Glasgow University which brought a team of Scottish engineering teachers led by Henry Dyer (just 24 years of age at the time) to Japan to oversee the opening of the engineering school which in 1877 became the Imperial College of Engineering (*Kobu Daigakko*), with the first 22 recipients of the Bachelor of Engineering (*Kogakushi*) degree graduating in 1879.

All the education was initially conducted in English (*Kyu Kobu Daigakko Shiryo*, 1931, p. 322) and the curriculum was modeled after the Royal Indian Engineering College in London and consisted of half lectures and half practical training in specially designated government-run engineering premises. This emphasis on industry technology and practical engineering applications remained even after the college was merged into the Tokyo Imperial University and became its Engineering Department in 1886 (Morikawa, 1991). As discussed in more detail below, those roots in British-style education that emphasized practical, technological applications (Mokyr, 1992) played an important role in the selection of talent into engineering faculty.

[6] We are currently extending the data beyond 1922.

Already when the Imperial University was launched in 1886, almost half of the faculty members were graduates of Tokyo University or Imperial College of Engineering (the two predecessors of the Imperial University). The fraction of Imperial Universities' graduates among Tokyo Imperial University engineering faculty reached 80% in 1901 and exceeded 90% by 1910 (Figure 1). Tables A1-A3 in the online appendix present descriptive statistics.[7]

[Figure 1 around here]

For some purposes it is useful to distinguish between two types of faculty—full and assistant professors (whom we also call "core faculty") and other faculty members such as part-time lecturers (whom we call "non-core faculty"). Some lecturer positions were temporary and subsequently converted into assistant professor positions, but most (more than two thirds) were part-time positions where the individuals kept their main jobs elsewhere (private or public sector, military, etc.). This resulted in significantly shorter tenure (the average tenure on the job of the core faculty was 13.3 years, while it was 5.4 years for part-time non-core faculty, with the difference in means statistically highly significant). The share of part-time lecturers among all faculty increased over time (Figure A1 in the online appendix) as the department increasingly relied on them in bringing practical experience into the classroom.

IV. Ability Sorting

A. Distribution of engineering faculty

The critical issue in building the system of higher technical education from scratch was how to fill faculty positions with the top talent. Studies by Japanese historians (e.g., Iwata, 2021) describe the process of faculty recruiting as focusing on the very top students: "candidates to become university

[7] Imperial University Calendars do not break down faculty appointments by divisions, but they list the faculty specialization and courses they taught. We inferred faculty division affiliation from this information. Faculty were assigned to "Others" division in Table A2 if they taught general education courses.

professors were those who graduated with honors and a special nurturing path was open to them" (*ibid*., p. 24). However, as the same studies point out, top graduates had many career choices, and their path to the country elite was by no means limited to the academic profession (*ibid.*, p. 141).

As it turns out, academic jobs were still disproportionately filled with top talent. Panel A in Table 1 shows that the share of Imperial University Engineering Department graduates in the graduation cohorts up to 1918 (the last cohort we have graduation rankings for) who became faculty at Tokyo Imperial University Engineering Department at least once in their careers (followed until 1939) was seven percent on average across all divisions and graduation cohorts. Importantly, however, this share was much higher among top-talented individuals. Consistent with the description in Iwata (2021), engineering faculty absorbed almost a third (32%) of all of its top-ranked graduates (those who were number one in their division cohorts measured by test scores and the quality of the final diploma work; Table 1, Panel B).[8] Figure 2 looks at this from a different angle by presenting the empirical cumulative distributions of university graduation rankings among Tokyo Imperial University engineering faculty—core faculty in Panel A and all faculty in Panel B. We observe similar patterns with regard to high-school graduation rankings (Figure A2 in the appendix), but the relationship is significantly less pronounced than for university graduation rankings, suggesting that selection on specialized knowledge might have been more important than that on general academic ability.

[Table 1 and Figure 2 around here]

Given plentiful career opportunities available elsewhere and high competition for top-notch talent in general and in Japan at that time in particular, what drove so many of the top-ranked

[8] Tokyo Imperial University engineering graduates also took positions as faculty in other Imperial Universities that were established later in our sample. If we add those, the share of Imperial Universities' faculty among all graduates increases to 10%, while the same share among top-ranked graduates increases to 41%.

graduates to nevertheless choose becoming engineering faculty? We discuss and present some historical evidence about potential selection mechanisms here and turn to structural estimations to quantify the roles played by those in the next section. The narrative follows the storyline of Tokyo Imperial University (by far the largest one and the one for which we have observations throughout the sample), but it is representative of all other later-established Imperial Universities too.

B. Potential selection mechanisms

We begin by noting that, while Tokyo Imperial University was generally able to attract and retain top talent, that had not necessarily been the case earlier in our sample period. The case of Ichisuke Fujioka (a top-ranked graduate and the founder of one of the predecessor companies of today's Toshiba) described in detail in Appendix C is a case in point. The University lost him to a private company that offered much better compensation shortly after his appointment as an assistant professor in 1886. More generally, the university did initially struggle to attract and retain top talent. In the first 14 years after it was founded (1886-1899), the annual quit rates by all 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 (Figure A3 in the online appendix). And while the turnover among the core faculty was a bit lower than among all faculty, it was still more than one third per year during those years. The average university graduation rankings of the engineering faculty (core and non-core) until 1899 were also relatively low, at about 0.75.

The situation started to change at the turn of the 20th century. The average graduation rankings of engineering faculty exceeded 0.8 and reached 0.9 in 1911-1920. The turnover and quit rates, especially among core faculty, plummeted to less than 10 percent and five percent, respectively, by the 1914-1920 period (Figure A3). In what follows we discuss several changes to the potential attractiveness of academic jobs that happened during our sample period.

Following the extant literature, we divide the potential factors affecting the choice of academic careers can into several categories—pecuniary compensation, non-pecuniary preferences ("taste for academia"), social status and prestige, and complementary assets.

B.1 Pecuniary compensation

While most of the extant literature emphasizes the role of non-pecuniary motivation in choosing academia over the private sector (e.g., Agarwal and Ohyama, 2013), the findings in that literature, as mentioned, are based on examining PhD degree recipients in the United States who may have strong intrinsic preferences for academic careers. Furthermore, in a generally poor country, such as Japan at the time, pecuniary incentives may generally play a higher role even for educational elite than in today's United States. We therefore start our discussion of potential selection mechanisms from pecuniary compensation.

The 10-volume one-hundred-year history of the University of Tokyo (*Tokyo Daigaku Hyakunenshi,* 1977) contains information about the evolution of salary schedules offered to the faculty during our sample. The schedules for core faculty (full and assistant professors), were first set explicitly by an Imperial Edict in 1893 and then changed by subsequent Imperial edicts as shown in Table A4 in the appendix. As can be seen from the table, the schedules exhibit high dispersion from top to bottom and we do not have information on which faculty member was allocated to which grade. Importantly, however, the overall evolution of the pay schedules exhibits a time trend to more pay differentiation among faculty with the same job titles. It is also worth noting that while until 1918, top assistant professors' salaries amounted to 50% of those of full professors, starting from 1919, those were increased to 2/3 of full professors. Together with the introduction of the mandatory retirement age around the same time, this indicates a shift in the University policy toward making its jobs more attractive to top younger talent.

Even more importantly, the 1893 Imperial Edict introduced the course chair system ("*Kozasei*") dividing the salaries into the basic salary (*honpo*), paid according to the scales in Table A4 and service allowance (*shokumuho*). While progression along the basic salary scale was tied to the length of service, the service allowance was unrelated to seniority and instead determined according to "the amount and difficulty" of courses taught (*Tokyo Daigaku Hyakunenshi,* 1977). The share of the service allowance in total compensation kept increasing over time, reaching 50% or more of the total compensation and allowing top faculty to earn much more than would have been possible otherwise (Nakayama, 1972, pp. 141-142). Provisions for merit increases as high as 30% or more of the total compensation were introduced in the 1897 and subsequent Imperial edicts, while the 1921 and 1922 Imperial Edicts provided extra compensation amounting up to 45% of average full professor salary and 61% of average assistant professor salary to those who also worked in affiliated research institutes at the same time. (We discuss the role played by those institutes as complementary assets to attract innovative talent below.) Overall, top-talented faculty was compensated better than an average engineering faculty member, reducing the overall gap with the private sector earnings noted in the studies by Japanese historians (e.g., Morikawa, 1975).

In Section IV below we develop and estimate a structural model of occupational choice that elucidates the relative role of pecuniary and non-pecuniary compensation while taking selection into account. Before that, we conduct here a preliminary comparison of the earnings of top talent who chose to be engineering faculty versus other sectors of the economy in a reduced form, using simple Mincer-type regressions and utilizing our hand-coded earnings data for top-ranked graduates collected from Japan's *Who is Who* for years between 1902-1922.[9]

[9] As mentioned, 1902 esd the first year *Who is Who* started publishing income tax data. *Who is Who* was not published in 1904 and the 1906 volume is missing, so we do not have the data for those two years. Data coding for years beyond 1922 is ongoing and we expect to update the findings here and in Section IV before the conference.

Specifically, we regress logged incomes on years after graduation, its square term, and dummies equal to one if the top-ranked graduate's primary job was (i) with Tokyo Imperial University Engineering Department or Engineering Department of another Imperial University; (ii) in industry (private or foreign sector); and (iii) in government or the military. In the second specification we add interaction terms between years after graduation and each of the dummies above. Graduation divisions (such as Civil Engineering, Applied Chemistry, etc.) and year fixed effects are included, and we limit the sample to 35 years or less after graduation.[10]

The estimation results are presented in Table 2. The coefficients on the years after graduation term in both specifications indicate that an extra year of post-graduation experience increased earnings by about 10%, with the negative coefficients on the quadratic term, as would be expected. In Column (1) the coefficient on the dummy equal to one if the top-ranked graduate was employed in the private sector indicates that such employment was associated with about 13% higher earnings compared to the baseline (employment in the government/miliary sector) and about nine percent higher earnings than for those employed in Imperial Universities. However, we cannot reject the hypothesis that statistically there was no difference between the earnings by top graduates who were engineering faculty and those employed in the private sector.

[Table 2 around here]

The estimation results in Column (2) indicate that earning profiles among top graduates employed in academia were significantly flatter than in the private sector and also flatter than in government/military employment. This is consistent with the findings in the extant literature (cf. Agarwal and Ohyama, 2013). Overall, it appears that top graduates who chose employment in

[10] We do not have birth years for all graduates, so we use years after graduation as a proxy for age. Among the graduates with age data, more than 80% graduated between ages 24 and 26, so that 35 years after graduation correspond to 60 years of age.

academia did take a discount in their wages compared to those who went to work in the private sector, especially later in their careers, but on average, this discount was not that large, at least in this reduced-form estimation. Of course, the simple regressions in this section do not take into account the selection into occupational choice and the results are therefore likely biased. We revisit these earnings differentials when we estimate the dynamic structural model in Section IV below.

B2. Non-pecuniary motivation

Extant literature has found that non-pecuniary attractions of an academic job can be related to the "taste for science" (Stern, 2004) and/or preferences for specific job attributes, such as intellectual challenge or intellectual freedom (Roach and Sauermann, 2010; Agarwal and Ohyama, 2013). Job security and independence can also be important. One reason for early struggles by the University to attract and retain top talent in early years of its existence noted above (see also Amano, 2004, Vol. 1) could be that those attributes were initially lacking, as faculty were considered to be hired employees of the Ministry of Education and tasked with educating future generations of government bureaucrats with little room for academic freedom (Nakayama, 1972, p. 52, 133).

The afore-mentioned 1893 Imperial Edict was an important milestone in not just improving monetary incentives, but also as a starting point for improving academic freedom and independence. The edict legally codified the role of department-based faculty assemblies (*Kyojukai*) as bodies with broad autonomy over decisions related to academic and education policies (*Tokyo Daigaku Hyakunenshi*, 1977, Vol. 1, p. 849-850). The assemblies which initially included only full professors were later expanded to include also assistant professors and lecturers, and the span of decisions delegated to them also kept increasing over time. For instance, in 1898, departmental faculty assemblies were given the right to make final decisions on the university side about conferring academic degrees which previously rested with the all-University Council (*ibid*.,

p. 973). Most importantly, while legally faculty assemblies could not make decisions on appointments and removals of the faculty, the informal norms, starting from the turn of the century, had expanded their de facto decisive role in making those decisions (*Tokyo Daigaku Hyakunenshi*, 1977, Vol. 2, p. 4).[11] All this led to increased job security and sense of autonomy and independence.

As it kept competing for top talent, the University implemented several other measures to boost the appeal of its faculty jobs. From the turn of the 20th century, the Engineering Department started systematically putting assistant professors on 2–3-year paid sabbaticals to study abroad at top universities in advanced nations. Our data show that while less than five percent of engineering faculty were on a sabbatical abroad in any given year in 1886-1899, this share more than doubled to 11 percent in 1900-1913 and remained high after that despite the disruption caused by World War I. The opportunity to engage in a study/research sabbatical at top foreign schools increased the appeal of faculty jobs to graduates with preferences for science, especially that the routine career path established at the same time involved promotion from assistant to full professor after completing the sabbatical as well as often also a recommendation for the doctoral degree conferral.

As a result, a culture emerged called "Meiji academism" (Nakayama, 1978, p. 150) providing strong non-pecuniary motivation to top talent to select into faculty jobs.

B3. Prestige and Social Status

As noted by Stern (2004), desire to receive recognition is another strong motivation for those who choose careers in academia. While it can be considered to be part of non-pecuniary motivation, the recent study by Gola (2024) differentiates occupational prestige as well as local status conceptually from other types of non-pecuniary motivation.

[11] In 1913, following a bitter conflict between the President of Kyoto Imperial University and its Law faculty over firing of a faculty member, the Ministry of Education issued the formal opinion requiring the President to consult with department assembly over faculty personnel decisions. The system of electing University Presidents by direct faculty vote (still in place in today's Japan) was introduced around the same time (Amano, 2004, Vol. 2, p. 348).

During initial years of its existence, the social prestige of an academic position with the Imperial University was not that high (Amano, 2004, Vol. 1, p. 199), but this also changed over time. To begin with, already at its founding in 1886, Imperial University professors and assistant professors were given the status of senior civil servants (*Soninkan*), whose appointments were made by the Prime-Minister, while up to 12 full professors could be given the highest status of Emperor-appointed civil servants (*Chokuninkan*) (*Tokyo Daigaku Hyakunenshi*, 1977). The restrictions on the number of Emperor-appointed professors were subsequently lifted, generating more opportunities for social status advancement. Also, after a brief and unsuccessful experiment with an American-style doctorate degree conferral through graduate education, the University resorted to granting doctorate degrees primarily by peers' recommendations (Amano, 2004, Vol. 1, pp. 195-196) further increasing the recognition (local status) motivation among the faculty.

As the Japanese economy grew and the number of graduates expanded, capacity constraints in academia raised the bar for talent further. As shown in Table 1, Panel A above, on average about seven percent of engineering graduates became Tokyo Imperial engineering faculty at some point in their careers across all graduation cohorts (about 10 percent if other Imperial faculty jobs are also included). In Table A5 in the appendix, we break this down into those who graduated before 1900 and in 1900-1918. As can be seen from that table, 11.3% of the graduates who graduated before 1900 became engineering faculty at Tokyo Imperial University at some point in their careers (13.8% including other Imperial Universities), but this share fell to less than six percent for those who graduated in the first two decades of the 20th century (9.1% including other Imperial Universities). Clearly, the number of graduates grew faster than the number of available academic jobs. At the same time, and in contrast to the overall dynamics, the fraction of those who became engineering faculty among the top graduates actually increased over time: while 29.2% among top

graduates with graduation years before 1900 became Tokyo University engineering faculty (38.1% including engineering faculty jobs at other Imperial Universities), this share rose to 33.8% (42.2%) among those who graduated in 1900-1918. Comparing these two trends indicates that capacity constraint may have made talent selection into faculty jobs even stronger. By itself, high occupation prestige under capacity constraints should lead to higher earnings in academia (Gola, 2024), offsetting the impact of non-pecuniary motivation. Thus, the question of whether academic jobs pay higher or lower wags compared to other sectors becomes an empirical one and we address it in the next section.

B4. Complementary assets

Successful recruitment of top talent through pecuniary and non-pecuniary channels translated into a disproportionately high share of engineering faculty with high innovation potential. Table 1, Panel C shows that the average share of those who became engineering faculty among eventual inventors (graduates with at least one patent before 1940) was 14.1 percent, twice as high as the share among all graduates, while the same share of engineering faculty among graduates who eventually became global inventors (graduates with at least one global patent) was more than three times higher than the share among all graduates, at 22.2 percent (Table 1, Panel D).

One problem that the university may have faced with respect to its industry innovation-oriented faculty was their potential desire to leave for private companies that would reward them more for innovation and also provide complementary assets. For instance, that appears to be the case for the afore-mentioned Ichisuke Fujioka. It is worth noting that as Fujioka resigned from his core faculty position, the Engineering Department immediately invited him to return as a part-time lecturer, the position he then held for 10 years while also founding his own startup which later became one of the two strands of today's Toshiba Corporation. In those early years Fujioka may

have been an outlier, but faculty combining science with its practical applications in industry eventually became widely accepted (Segawa, 1933, Part IV, pp. 54-56).

Starting from the turn of the 20th century and especially as the Second Industrial Revolution picked up steam, the university started encouraging more collaboration with government research agencies and private companies, as well as hiring more industry scientists as part-time lecturers (the increase in their share among all faculty was shown above, in Figure 1). The emphasis on industry-applied research became more pronounce as Meiji era changed to Taisho (in 1912) (Nakayama, 1972, pp .164-165). The most tangible signs of this shift of emphasis can be seen in the establishment of muliple research institutions affiliated with the Imperial Universities, which allowed faculty to conduct applied research without being constrained by the course chair system or even department boundaries (*ibid*., pp. 168-169). One of the most important such institutes was the Institute of Aeronautics, inaugurated under Tokyo Imperial University in 1918. Its name notwithstanding, it provided a venue for applied research in a variety of areas, from aerodynamics, to engines, to measuring instruments, to materials engineering (Vol. 7 of *Tokyo Daigaku Hyakunenshi*, 1977, presents a detailed account of the Institute's history from its inception). The Institute employed 62 engineering faculty members in our sample at some point between 1918-1939, including some of the most prolific inventors among all engineering graduates and paid them extra compensation for combining teaching and research as noted above.[12] In 1925, Tokyo Imperial University inaugurated the Earthquake Institute, headed by Kyoji Suehiro, Professor at the Naval Architecture division and a consultant to the private giant corporation, Mitsubishi Shipbuilding Co. See appendix C for the details of Suehiro's biography which illustrates the role of complementary assets and rewards in generating industry innovation by the engineering faculty.

[12] For example, Kiyoshi Tomizuka, a 1917 graduate of the Engineering Department served as a professor at the Engineering Department and a researcher at the Institute of Aeronautics, generating 78 industry-related patents.

Another important research institute closely associated with the Imperial University although formally not under it was *Riken*, the Institute of Physical and Chemical Research (currently a National Research and Development Agency). *Riken* was launched as a private institution, modeled after the Kaiser Wilhelm Society in Germany in 1917 but struggled to get traction until Masatoshi Okochi, a prominent professor and prolific inventor at the Engineering Department of Tokyo Imperial University was appointed its director in 1921. Okochi transformed *Riken*'s organizational structure by introducing a system of independent labs with Engineering and Science Department scholars in charge of each labs that bore their names, with full autonomy to manage research topics, personnel and budget. Appendix C provides more details.

Thirty-three full-time faculty members in our data headed various labs in *Riken* at some point during our sample period, 24 of whom had at least one patent during those years. The total number of patents produced by inventors-academic faculty members in our sample over the period of 1917-1939 was 369, accounting for about 5.3% of all patents generated by all Imperial Universities' graduates in our sample over the same period.[13]

The creation of complementary assets for applied industry research by the University helped attract and retain top innovative talent which contributed to Japan's academia becoming a hot-bed for generating industry-related technologies and their commercialization.

V. Structural Model of Occupational Choice

We have seen that engineering faculty (academic careers) were disproportionately chosen by the top talent among the graduates. We also saw that, not taking selection into different occupation into account, engineering faculty on average earned about 12.7% less than those who worked for

[13] *Riken* was so successful in developing industry technologies that it spun off a whole bunch of companies (Riken Industrial Group) aimed at commercializing its technologies, which included high-tech firms, such as Ricoh, which still survive to the present day (see e.g., Saito, 1996).

the private sector, although perhaps somewhat more than their peers who chose to work in the public/military sector. We now tun to a simple dynamic structural model of occupational choice to examine the relative importance of pecuniary and non-pecuniary incentives while taking occupational choice decisions explicitly into account. The sample is once again limited to top-ranked graduates, so that the population is comprised of the best of the best among their peers in terms of observed (academic) achievement. The model is a simplified version of the seminal model proposed by Keane and Wolpin (1997) (see also Traiberman, 2019).

A. 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 ($j = 3$).[14] Individuals get utility from both earnings $w_{ij}(a)$ and non-pecuniary gains (age-invariant gain ω_{ij} and age-variant gain $\rho\varepsilon_{ij}(a)$) if they choose occupation j. They also have to incur a job switching cost $c_j(a)$ each time they change their 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 reward for an individual at age a is:

$$R_{ij}(a) = w_{ij}(a) - c_j(a)\big[1 - d_{ij}(a)\big] + \omega_{ij} + \rho\varepsilon_{ij}(a), \qquad (j = 1, 2, 3)$$

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, while ρ is a scaling parameter. Since non-

[14] Keane and Wolpin (1997) assume the fourth option of staying at home and most literature have this option which includes being unemployed. In our data, we cannot distinguish between staying at home (being unemployed) and missing data, so we treat observations with missing employer (occupation) data as missing. It should be mentioned that top-ranked graduates of the Imperial University who are used for the structural estimation in this section were a very scarce resource and in high demand in Japan at that time, so unemployment among them was a very unlikely event.

pecuniary gains are additive invariant, we normalize the gains in industry to 0, so ω_{ij} represents the gains relative to industry. The (logged) wage process for individual i in sector j is given by:

$$\ln w_{ij}(a) = b_{j0} + b_{j1}a + b_{j2}a^2 + \nu_{ij} + \varsigma_{ij}(a),$$

where ν_{ij} is an individual-specific earning potential (with the mean of 0) and $\{\varsigma_{ij}(a)\}_{j=1}^{3}$ are an ex post idiosyncratic earning shocks that depend on age a and follow joint normal distribution $N(0, \Sigma)$ independently. We assume that individuals observe these idiosyncratic shocks after they choose occupation. The switching cost function takes the following log-linear form:

$$\ln c_j(a) = c_{j0} + c_{j1}a + c_{j2}a^2.$$

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). We normalize the cost of moving to industry to 0.

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

$$V_i\big(S_i(a)\big) = \max_{d_{ij}(a)} \ E\left[\sum_{h=0}^{A-a} \delta^h \sum_{j=1}^{3} R_{ij}(a+h)d_{ij}(a+h) \,\middle|\, S_i(a)\right].$$

Using the choice-specific value function $V_{ij}\big(S_i(a)\big)$ for $= 1, 2, 3$, the value function satisfies the following Bellman equation:

$$V_i\big(S_i(a)\big) = \max_j\{V_{ij}\big(S_i(a)\big)\},$$

$$V_{ij}\big(S_i(a)\big) = E\big[R_{ij}(a) \mid S_i(a)\big] + \delta E\big[V_i\big(S_i(a+1)\big) \mid S_i(a),\ d_{ij}(a) = 1\big]$$

$$V_{ij}\big(S_i(A)\big) = R_{ij}(A)$$

The expectation operator is taken over the distributions of current $\varsigma_{ij}(a)$ and future $\varepsilon_{ij}(a)$ and $\varsigma_{ij}(a)$ conditional on $S_i(a)$. If we define $\tilde{V}_{ij}\left(\tilde{S}_i(a)\right) = V_{ij}\big(S_i(a)\big) - \rho\varepsilon_{ij}(a)$ where $\tilde{S}_i(a) = \{a,$

$\{d_{ij}(a-1),\ \omega_{ij},\ \nu_{ij}\}_{j=1}^{3}\}$, the distributional assumption of $\varepsilon_{ij}(a)$ implies that the occupation choice probability at age a can be written as the logit form:

$$f\left(d_{ij}(a)=1\middle|\tilde{S}_i(a)\right)=\frac{\exp\left(\tilde{V}_{ij}\left(\tilde{S}_i(a)\right)/\rho\right)}{\sum_k \exp\left(\tilde{V}_{ik}\left(\tilde{S}_i(a)\right)/\rho\right)}.$$

Therefore, given graduates' age, lagged 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.

B. Estimation Methodology and Results

We estimate the model using the data on top graduates, $i=1,\ldots,N$, that consists of the set of occupation choices and earnings, $\{d_{ij}(a),\ w_i(a)\}$. The parameters we estimate are collected into the set denoted by θ. Following the common approach in the literature, we assume that graduates are categorized into Q types and indexed by q. In this version of the model, we categorize graduates into four categories. Denote the probability of being type q by p_{iq}. Then, the likelihood of the observed data can be written as a finite mixture of type-specific likelihoods:

$$L(\theta)=\prod_{i=1}^{N}\left(\sum_{q=1}^{Q}p_{iq}\left[\prod_{a=1}^{A}f\left(d_{ij}(a)=1\middle|\tilde{S}_i(a),\ \theta\right)g\left(\ln w_{ij}(a)\middle|\tilde{S}_i(a),\ \theta\right)\right]\right),$$

where g is the normal probability density. We use the sequential EM algorithm as in Arcidiacono and Jones (2003) to estimate the underlying parameters. We first estimate the parameter set θ (pecuniary returns and non-pecuniary preferences) governing occupational choices and earnings via maximum likelihood, treating the conditional probability of being each type p_{iq} as given. The next step in the estimation procedure is to estimate the posterior probabilities of each graduate being assigned to each of the four types, conditional on the estimated type-specific set of

parameters. The estimation then iterates these two steps until it converges to the probabilities of each type and the parameter set θ that fits the empirical data.

Key estimated parameter values for each type as well as the distribution of graduates' probabilities of belonging to each of the four types are presented in Table 3.[15] Starting with graduates classified into Type IV, those are "stars" who have very high earning potential, especially in academia (but also in the private sectors) while their non-pecuniary utility parameters are negative for academia and especially the public/military sector. Average earnings are about 11,000 yen per year for Type IV top graduates in our data (see Table 4 below), so given the non-pecuniary utility of -3,182 yen in academia and -9,188 yen in the public/military sector, an average Type IV individual would require a 30% increase in salary to be indifferent between being in academia and the private sector, and a whopping more than 80% salary increase to agree to be employed by the government or the military. Type IV "stars" account for slightly less than nine percent of all observations and the combination of earnings potential and non-pecuniary preferences suggests that they should predominantly select into the private sector.

[Table 3 around here]

The rest of the sample (the "non-stars") is distributed roughly equally among all top graduates into Types I, II, and III (around 30% in each type). Type I graduates have high earning potentials in the public sector/military and somewhat high in academia, but low in the private sector. Thus, from the productivity perspective, their best fit is as a government employee/military officer. Their non-pecuniary preferences show the opposite pattern, however—they prefer to be in the private sector as opposed to academia or public sector/military, with more negative attitude toward government/military employment than academia. The combination of high earnings

[15] All the structural estimation results presented in this draft are very preliminary as we are currently extending the earnings data beyond 1922. If accepted, we will be able to present updated results at the conference.

potential in the public sector with strong non-pecuniary aversion to public-sector employment, together with somewhat lower (but high compared to the private sector) earnings potential in academia and more or less neutral attitude toward academia suggests that we may see these individuals choose academic jobs, depending on idiosyncratic circumstances.

Type II individuals exhibit the pattern which is the opposite of Type I. Their earnings potential is relatively high in the private sector, while their earnings potential as members of engineering faculty is low. However, they have strong non-pecuniary preference for academia (and also for the public/military sector employment). The average earnings of this type in academia per Table 4 is 2,015 yen, so they would need their salary to be almost triple of what they receive on average in academia to induce them to move to the private sector. This comparison is not relevant, however, as their second-best choice is the public/military sector, not private sector. Type II individuals will only require about 20% higher salary in government or military employment to make them equally happy as they are in academia. We can thus expect to see Type II graduates in both academia and public/military sector employment.

Finally, Type III individuals generally have low earnings potential throughout, but their disadvantage is relatively smaller in the private sector. They also have an aversion to academia but positive non-pecuniary preferences in the public sector. We can thus expect to see individuals of this type in industry or the public/military sector but not in academia.

Table 4 shows how the four types above translate into actual outcomes in the data. Graduates of Types I and II are most likely to choose engineering faculty (Imperial University academic) jobs, with 43.6% and 42.0% among each type selecting those jobs, respectively. Consistent with the difference in preferences, Type II graduates' real earnings (nominal annual earnings, deflated by the consumer price index) are about 17% lower than Type I earnings.

Conditional on becoming engineering faculty, the gap is even much wider, with Type II graduates' real earnings almost 45% lower than for Type I graduates. We present some examples of members of engineering faculty classified into each type in the next subsection.

[Table 4 around here]

As can be seen from Table 4, just over two percent among Type III individuals select into academic jobs. As for Type IV (the stars), less than nine percent of observations on this type of graduates are in academia, with the rest (as we show in the next subsection) employed entirely in the private sector (industry).

C. Estimation Results Through the Prism of Historical Data

Twenty-six among 297 top-rank graduates in our sample are classified into Type IV (stars) by our structural estimation above. As shown in Table 4, those "stars" held engineering faculty jobs in less than nine percent of all observations, while all the rest are in the private sector (industry). The two individuals who also held jobs in academia are Kingo Tatsuno and Masatoshi Okochi. Tatsuno was the 1879 (first graduation cohort) top-ranked graduate from the architecture division, so when he entered our sample in 1902, he was already mid-career. One of his most famous designs is that of the Bank of Japan headquarters in Tokyo which he designed in 1890 while working as engineering faculty. Tatsuno quit his engineering faculty job in 1903 to found and manage his own architectural design company where he remained until he passed away in 1919 at the age of 64. His career path is thus consistent with the characterization of Type IV graduates as having a strong preference for industry (private sector) jobs even though they have even higher earnings potential in academia. As for Okochi (see also Section III B4 above and Appendix C for more details about him), he had been engineering faculty since he graduated in 1903 and throughout our current sample period (which ends in 1922), but he actually quit his academic job to focus on managing

the *Riken Industrial Group* in 1925. In this sense, his case presents validation "outside of the sample" of our estimates as his transition to the private sector happened outside of our sample time frame and thus could not have affected the estimations.

Three graduates classified into Type II by our structural estimation present another interesting validation "outside the sample." Shozo Arisaka, Kumaji Kusunose, and Yuzuru Hiraga all served in the Navy which they themselves and their biographers list as their main jobs. At the same time, they also held appointments as full professors in the Tokyo Imperial University. Being their second jobs, those appointments were not reflected in occupational choice data used for our structural estimation. Nevertheless, all three turned out to be Type II with strong preferences for academia, reassuring that structural estimations are picking up some essential individual characteristics outside of the sample. (Hiraga actually became President of Tokyo Imperial University in 1938, way outside of our estimation period.)

Ariya Inokuty is an example of a graduate-engineering faculty assigned by our estimation procedure to Type I. His relatively high preference for the innovation and the private sector can be seen in the fact that he invented a centrifugal pump that was given his name, took a patent, and then helped his former student found Ebara Corporation, the company based on his invention which still survives until the present day (https://www.ebara.co.jp/en/). Inokuty himself, however, never left academia, and if our estimates are correct, that was the right occupational choice for him.

VI. The Formation of Preferences for Academia and Reduced Form Validation

A. Academic ability and preferences for academia

Are mentioned, the literature has conjectured that ability and non-pecuniary preferences for academic career might be correlated (e.g., Stern, 2004). Is this just a correlation or at the stage of occupational choice, or the relationship driven by some deeper factors? Our data provide us with

a unique window of opportunity to look more deeply into the relationship between ability and the formation of preferences.

Recall that in addition to university graduation rankings, we also have the data on the graduates' rankings relative to peers as they graduated from high schools as well as the data on how they were ranked after the first two years of coursework at the university. While the sample we used for structural estimation in the previous section is comprised of graduates who were ranked at the top of their division-cohorts at the time of graduation, there is still variation in how they were ranked before that, in high schools and after two years at the university. Table 4 above shows that on average less than 30% of all top-ranked university graduates were also ranked at the top of their high-school cohorts. And while almost 71% were already ranked at the top when finishing their second year in the university, still almost 30% only moved up to the top after finishing the last year of university study.

As can be seen from Table 4, Type II graduates (those with strong non-pecuniary preference for academia) stand out among other categories in the shares of those ranked at the top both at the time of graduating from high schools and after two years of university coursework. Thus, preferences for academic job displayed in occupational choice decisions after graduation appear to be related to earlier educational achievements by individuals, even conditioning, as we do in this sample, on being a top achiever at the time of graduation and career choice.

Potentially, there could be two, mutually not exclusive stories behind this finding. One is that some people have high intrinsic preferences for academia and knowing that the Imperial University generally demanded high-ability graduates (Iwata, 2021), they made extra effort already in high school to be ranked at the top. Another story (which looks even more attractive to us) is that preference for academia is actually an acquired one—acquired by those who discover

that they are good at absorbing knowledge already in high school (and possibly even earlier than that). In this interpretation, students whose ability places them at the top in early stages of their education, develop the "taste for science" as they enjoy absorbing higher-level knowledge. Either way, we see evidence that students with preference for academia were already top students early on and therefore, the correlation between ability and preference for academia holds in a deeper sense, even for those who eventually all graduated at the very top of their cohorts.

While the findings in Table 4 are based on structural estimation, we validated them also in a simple reduced form. For this purpose, we divided the engineering faculty at Imperial University Universities into "high" and "low" earners, where high earners are those whose individual fixed-effects earnings (after controlling for years after graduation and years after graduation squared) were above the median while low earners are the rest. Table A6 in the appendix shows that low earners were much more likely that high earners to have graduated at the top of their high school cohorts and also to have been at the top of their cohorts in the university already after the first two years. This pattern is consistent with the patten in Table 4 showing that among the top graduates, those who were classified as Type II (with strong non-pecuniary preference for academia) had already been top students before graduation, so that their lower earnings in academia are due not to lower ability but to discounts they are taking based on their non-pecuniary preferences.

B. Preferences for Academia and Cohort Composition

In the last two rows of Table 4 we split observations on each type of graduates by cohorts that graduated before 1900 and in 1900-1918. What we see is a big increase in the relative number of Type II graduates (those with high preferences for academia) among graduates from the post-1900 cohorts—just 17% of all graduates are assigned to this type among earlier cohorts (less than half the number of Type I graduates in those cohorts), but the share of Type II graduates increases to

one-third among top graduates from later cohorts, and their number is now equal to the number of Type I graduates. Reflecting this, while the share of top graduates who become faculty is the same across all cohorts, later cohorts have a much larger share of faculty of Type II, that is, those who join academia driven by non-pecuniary preferences. Thus, our structural estimation results indicate that the Engineering Department produced relatively more graduates who were interested in academic jobs for their own sake among later cohorts than among earlier cohorts. What drove this change?

It seems that the main reason was that as academia found itself competing against higher salaries in the private sector and experienced initial difficulties in recruiting and retaining top talent, the university (universities) responded by improving the non-salary benefits. As we saw in Section III, the average salaries of engineering faculty had not changed that much, at least in real terms, over the 20 years of our sample. However, as the University implemented various institution-building measures described in that section, it created a lot of non-pecuniary incentives to prospective faculty, from increased social status and prestige associated with academic jobs, to academic freedom and self-governance, to the system of sabbatical, to important complementary assets for doing innovation-related research that had previously only been available in other sectors (such as government research institutions). We can conjecture that as these changes became noticed by new cohorts of students, they contributed to those cohorts developing interest in academic jobs even irrespective of pecuniary compensation. In turn, this led to an endogenous increase in the share of graduates with taste for academia. This conjecture can be confirmed also through direct evidence from raw data presented in the last three rows of Table A6—among the top graduates who joined engineering faculty, later cohorts were comprised of disproportionately many "low earners," that is, those who did not mind lower earnings in academia in exchange for

non-pecuniary benefits. Thus, the effort by academia to increase the attractiveness of the profession helped shape the preferences of more graduates from later cohorts toward those non-pecuniary benefits. This had extremely important consequences not just for the role of universities in contemporaneous development, but also in transmitting knowledge to new generations – something we plan to examine in a companion paper.

VII. Counterfactual Simulation

We saw that non-pecuniary benefits played a big role in attracting top graduates to faculty positions in academia; increasingly so over time as the university made the strategic choice to increase such benefits and provide more complementary assets since it found it hard to compete especially with the private sector on the dimension of monetary compensation. Suppose that the university did not do anything to make faculty jobs attractive from the non-pecuniary perspective. What may have happened to the allocation of talent to faculty jobs if non-pecuniary motive did not exist? We address this question here by simulating the counterfactual world where individuals don't put any weight on non-pecuniary preferences when making decisions about their occupational choice.

In Figure 3, we show the shares of individuals in academia and other sectors by age (Panel A) and age earnings profiles (Panel B) in the actual data (black line), simulated data using our structural estimation (blue line), and simulated data from the counterfactual estimation (red line). Simulated data were constructed as follows. We first used the estimated probability of an individual belonging to each of the four types above to assign them to just one type based on which type had the highest probability.[16] Next, using estimated parameters and types assigned in the previous step, we repeated the simulations for occupation choices and earnings profiles for each

[16] Alternatively, we could use weighted probability of being each of the four types. We implemented the counterfactual simulation in this way too and the results were very similar to those presented here.

individual 10 times. The blue line depicts the average over all 10 simulations of the data simulated using actual estimated parameters, while the red line depicts the average over all 10 simulations of the data simulated using all the same parameters but with non-pecuniary preferences parameters all set equal to zero, so that individuals are only guided by pecuniary motives.

[Figure 3 around here]

As can be seen from Figure 3, Panel A, the simulated data fit the share of individuals by age in academia reasonably well, although it underestimates this share somewhat during middle age and overestimates at the old age. Not surprisingly, in the counterfactual world with no non-pecuniary preferences (either for academia or for any other sector for that matter), the share of those choosing academia is estimated about half of that than in the actual data and in the simulated data with our estimated non-pecuniary preferences parameter. Recall that the sample is limited to top-talent graduates. Therefore, the counterfactual estimates do not imply that academia would remain understaffed if non-pecuniary incentives were lacking. The vacant positions would probably still have been filled, just not by top graduates. Thus, the counterfactual estimates suggest that that non-pecuniary preferences were crucial in attracting more *top-ranked* graduates to faculty jobs. It is also worth noting that the differences are most pronounced at young age and decline to almost zero for older individuals. This is driven by increasing mobility costs, and it suggests that high mobility costs can be a substitute for non-pecuniary preferences as they increase with age.

Panel B shows that faculty earnings in simulated data fit the actual data quite well, except for the first five years or so after graduation, during which period we see very few individuals making it to Who is Who, so the observation sample is quite small. In the counterfactual estimation (with no non-pecuniary preferences), earnings of those top graduates who still choose academia are much higher, especially after middle age. Indeed, while actual age earnings profiles and

simulated such profiles among top-ranked graduates in academia using our estimated parameters peak out at about 4,000 yen around 20 years after graduation and remain flat after that, the counterfactual earning profiles in academia keep increasing and peak out at around 6,000-7,000 yen close to 30 years after graduation. Comparing this with actual age earnings profiles among top graduates who did not choose careers in academia, we see that counterfactual age earnings profiles in academia exhibit almost the same, if not even steeper increases than actual (or simulated, for that matter, including counterfactual simulations) age earnings profiles in the other sectors. Thus, if there are no non-pecuniary benefits in academia, the top graduates who still chose to be in academia are estimated to be earning the same, if not more, conditional on age, as those who go to other sectors, including if we limit the comparison to only the private sector (not shown separately).

Since the sample used for these estimations is that of top-ranked graduates, it is probably not surprising that absent non-pecuniary motivation they would on average be earning the same in any employment To put it differently, our counterfactual estimations suggest that without the "taste" for academic jobs, (a) much fewer top-talented graduates would be joining academia at young age, and (b) the University would have to pay much higher salaries to those top-talented individuals who do become faculty (at least 50% higher salaries 20 years after graduation and beyond). In terms of raw data in Table A6 in the appendix, this suggests that the University may have lost all its "low earners" who chose academia thanks to high non-pecuniary preferences and would be left with only half of its actual sample of top graduates, namely, those who were high earners (and whose earnings can be seen to be even higher than average earnings in non-academia).

As we saw in the previous section, the "taste for academia" was to a large degree generated endogenously among later cohorts of graduates through deliberate strategic moves by the university. Thus, all the measures taken by the university to improve the non-pecuniary

attractiveness of faculty jobs described in Section III did indeed play a key role in assembling faculty comprised of top-notch talent.

VIII. Conclusions and Discussion

We have shown that during its modernization in Meiji-Taisho era, Japan was able to ensure the selection into engineering faculty academic jobs of engineering graduates with top-ranked ability. Examination of historical evidence and structural estimation of a dynamic model of occupational choice have revealed that non-pecuniary motivation played a big role in attracting top-notch talent into academia despite the fact that the private sector increasingly offered higher salaries. Furthermore, using the historical nature of the data and leveraging the development of the academic profession from scratch, we were able to observe how non-pecuniary motivation for becoming faculty gained more importance over time as the University conducted various measures to promote such motivation and enhance the social prestige of the academic occupation, as well as the atmosphere of independence and academic freedom. Indeed, it appears that the graduates' preferences changed endogenously as non-pecuniary incentives in academia increased and the attractiveness of faculty jobs increased correspondingly. This kind of endogenous evolution of preferences in response to institutional changes can only be seen in long-term historical studies like this one, which we think makes our exercise especially interesting.

We also found that ability (academic achievement) and preferences for academic jobs were positively correlated. Furthermore, we saw that this relationship held in early stages in the graduates' educational process, even conditioning on everybody being top ranked when they graduated from the university. This suggests that individuals may have acquired "the taste for science" as they discovered they were good at it already while they were in high school.

By making sure that top talent selected into faculty jobs, the University also attracted scientists and engineers with high innovative potential who generated important new industry technologies. Realizing this, the University built affiliated research institutes, giving faculty academic freedom to engage in applied industry-related research of their liking and be rewarded for their innovations. This helped retain top innovators and also contributed to turning the Imperial University Engineering Department into a hotbed of innovations, especially in electric engineering and applied chemistry that were crucially important at that stage of Japan's industrialization.

There is evidence that top talent assembled in engineering faculty contributed to the intergenerational knowledge transfer. In the companion paper we are investigating how teachers, especially those of them who generated new industry-related technologies, contributed not just to contemporaneous development of the Japanese economy but also to the creation and development of future talent who would then, in its turn, become new engineering faculty and contribute to producing even more innovators among their own students.

Japan's industrialization in the late 19th-early 20th century presents a historical example that some late-comers to industrialization could emulated since then, but many less developed countries still haven't been able to emulate. By uncovering the mechanisms through which top talent was allocated to engineering faculty while the country had been building the higher technical education from scratch, we hope to contribute, in particular, to the understanding of the process that can result in individuals with high potential to excel in science and engineering to be allocated to academic jobs, critical for both contemporaneous and future innovation and growth.

References

Agarwal, R. and Ohyama, A. (2013). Industry of academia, basic or applied? Career choices and earnings trajectories of scientists. *Management Science*, *59*(4), 950-970.

Amano, I. (2004). *Daigaku-no Tanjo* (The Birth of Universities, in Japanese), Vol. 1-2. Chuko Shinsho, Tokyo.

Arcidiacono, P. and J. B. Jones (2003). Finite mixture distributions, sequential likelihood and the EM algorithm, *Econometrica*, 71, 933–946.

Becker, S. O., Hornung, E., and Woessmann, L (2011). Education and catch-up in the industrial revolution. *American Economic Journal: Macroeconomics*, *3*(3), 92-126.

Barro, R.J. and Lee, J-W. (2015) *Education Matters: Global Schooling Gains from the 19th to the 21st Century.* Oxford University Press.

Braguinsky, S., Ohyama, A., Okazaki, T., and Syverson, C. (2021). Product Innovation, Product Diversification, and Firm Growth: Evidence from Japan's Early Industrialization. *American Economic Review*, *111*(12), 3795-3826

Dyer, H. (1904). *Dai Nippon: The Britain of the East. A Study in National Evolution.* Blackie & Son, London, Glasgow, and Dublin.

Godo Y. and Hayami, Y. (2002). Catching up in education in the economic catch-up of Japan with the United States, 1890-1990. *Economic Development and Cultural Change, 50*(4), 961-978.

Gola, P. (2024). On the importance of social status for occupational sorting. *Economic Journal*, 134, 2009-2040.

Goldin, C. (2001). The human-capital century and American leadership: Virtues of the past. *Journal of Economic History, 61*(2), 263-292.

Goldin, C., & Katz, L. F. (1998). The origins of technology-skill complementarity. *The Quarterly Journal of Economics*, *113*(3), 693-732.

Gospel, H.F. (1991). *Industrial Training and Technological Innovation*: *A Comparative and Historical Study.* Routledge, London.

Hvide, H. K., and Jones, B. F. (2018). University innovation and the professor's privilege. *American Economic Review*, *108*(7), 1860-1898.

Iwata, K. (2021). *Kindai Nihon-no Daigaku Kyojushoku—Akademikku Purofession-no Kyaria Keisei* (Academic Profession in Modern Japan—the Career Path of the Profession, in Japanese). Tokyo, Tamagawa Daigaku Shuppanbu.

Jaffe, A. (1989). Real effects of academic research. *American Economic Review*, *79*(5), 957-970.

Kyu Kobu Daigakko Shiryo (Materials of the Former Imperial College of Engineering, in Japanese). (1931). Toranomon-kai, Tokyo. Available at https://dl.ndl.go.jp/pid/1464148/1/1

Landes, D.S. (1998). *The Wealth and Poverty of Nations*. W.W. Norton.

Maloney, W.F. and Caicedo F. V. (2022). Engineering Growth. *Journal of the European Economic Association*, *20*(4), 1554-1594.

Mokyr, J. (1992). *Lever of Riches: Technological Creativity and Economic Progress*. Oxford University Press.

Morikawa, H. (1991). The education of engineers in modern Japan: an historical perspective. In Gospel, H.F., ed. *Industrial Training and Technological Innovation*: *A Comparative and Historical Study*. Routledge, London, pp. 136-147.

Morikawa, H. (1975). *Gijutusha—Nihon Kindaika-no Ninai-te* (Engineers—The bearers of Japan's modernization, in Japanese). Tokyo, Nihon Keizai Shimbunsha.

Nakayama, S. (1978). *Teikoku Daigaku-no Tanjo* (The Birth of the Imperial University, in Japanese). Chuko Shinsho, Tokyo.

Nelson R.R. and Rosenberg, N. (1993). *Technical Innovation and National Systems. Chapter 1 in Nelson R., ed., National Innovation Systems: A Comparative Analysis*. Oxford University Press, 3-21.

Nicholas, T. (2011). The origins of Japanese technological modernization. *Explorations in Economic History, 48*, 272-291.

Nihon Shinshiroku (Who is Who in Japan, in Japanese), 1902-1939. Available at: https://ndlsearch.ndl.go.jp/search?cs=bib&display=panel&from=0&size=20&sort=published:asc&q-title=日本紳士録&f-ht=ndl&f-ht=library&f-ht=internet

Ramsey, M., MacMillan, D. (2015). Carnegie Mellon reels after Uber lures away researchers. *Wall Street Journal, May 31.*

Roach M., and Sauermann, H. (2024). Can technology startups hire talented early employees? Ability, preferences, and employee first job choice. *Management Science*, 70(6), 3619-3644.

Roach M., and Sauermann, H. (2010). A taste for science? PhD scientists' academic orientation and self-selection into research careers in industry. *Research Policy*, 39, 422-434.

Romer, P.M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(5, Pt. II), S71-S102.

Segawa, H. (ed.) (1933). *Kogaku Hakase Fujioka Ichisuke Deni* (Biography of Ichisuke Fujioka, Dr. of Engineering, in Japanese). Tokyo, Denki Nipposha.

Squicciarini, M. P., and Voigtländer, N. (2015). Human capital and industrialization: Evidence from the age of enlightenment. *The Quarterly Journal of Economics*, *130*(4), 1825-1883.

Stern, S. (2004). "Do scientists pay to be scientists?" *Management Science*, 50(6), 835-853.

Tokyo Teikoku Daigaku Hyaku-nenshi (100-year History of Tokyo Imperial University, in Japanese) (1977), in 10 volumes. Tokyo, Tokyo Imperial University. Available at https://www.u-tokyo.ac.jp/adm/history/03_03_j.html .

Tokyo Teikoku Daigaku Ichiran (aka *Tokyo Teikoku Daigaku Yoran* in some years) (Tokyo Imperial University Calendar), 1886-1939. Tokyo Imperial University. Available at https://ndlsearch.ndl.go.jp/search?cs=bib&display=panel&from=0&size=20&keyword=東京帝国大学一覧&q-title=東京帝国大学一覧&r-year=1886,1939&f-ht=ndl&f-ht=library and https://ndlsearch.ndl.go.jp/search?cs=bib&display=panel&from=0&size=20&q-title=東京帝国大学要覧&r-year=1886,1939&f-ht=ndl&f-ht=library ; select years available in English at https://ndlsearch.ndl.go.jp/books/R100000002-I000006483892

Toivanen, O., and Väänänen, L. (2016). Education and invention. *Review of Economics and Statistics*, *98*(2), 382-396.

Traiberman, S. (2019) Occupation and import competition: Evidence from Denmark. *American Economic Review*, 109(12), 4260-4301.

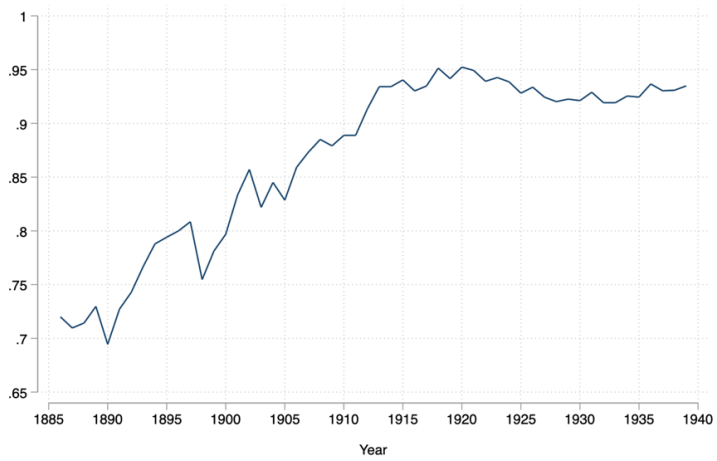
Valero, A., and Van Reenen, J. (2019). The economic impact of universities: Evidence from across the globe. *Economics of Education Review*, *68*, 53-67.

Yamaguchi, S., Inoue, H., Nakajima, K., Okazaki, T., Saito, Y., and Braguinsky, S. (2022). Invention by College Graduates in Science and Engineering during Japan's Industrialization. RIETI Discussion Paper Series 22-E-104.

Yamaguchi, S., Braguinsky S., and Nakajima, K. (2021). Science and engineering education and invention in Japan's industrialization. University of Maryland Ed Snider Center Working Paper No. 3, available at https://drive.google.com/file/d/16YrncMlmeq4NZ7KRhNeEWGRAQjwYA7op/view

Figures and Tables

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



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

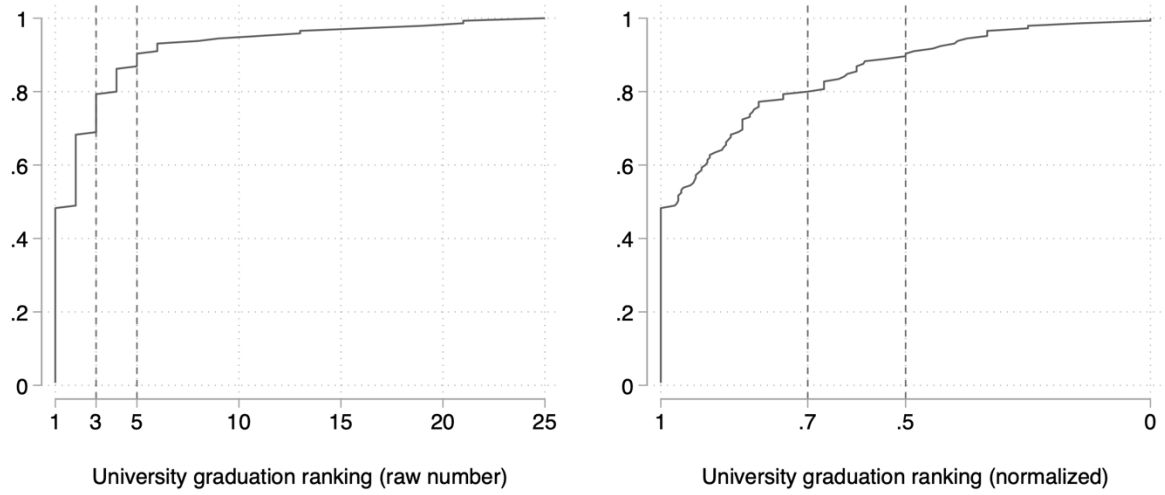
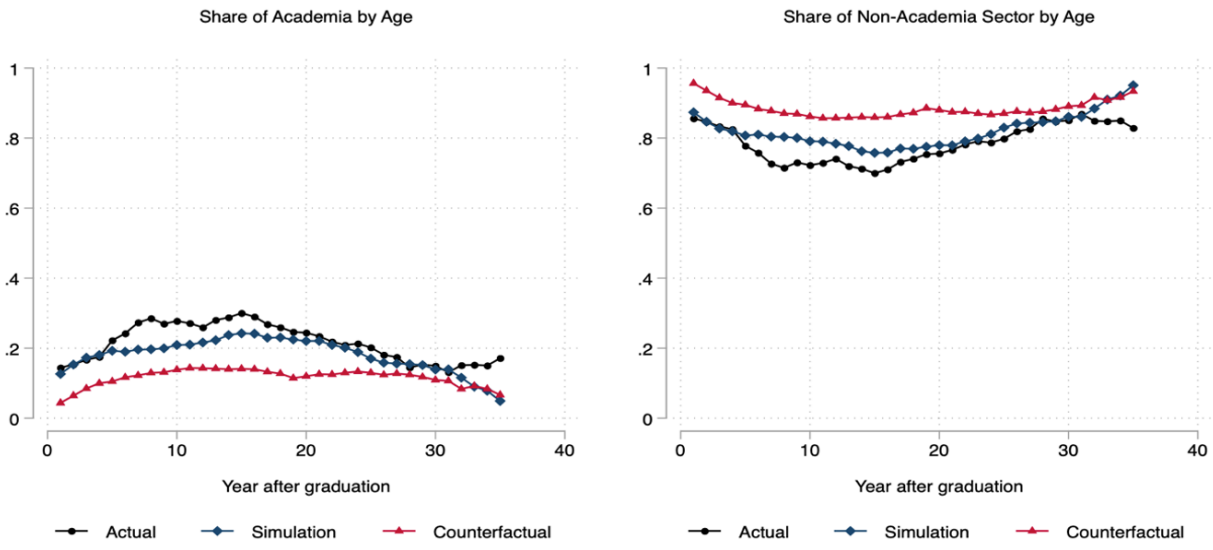
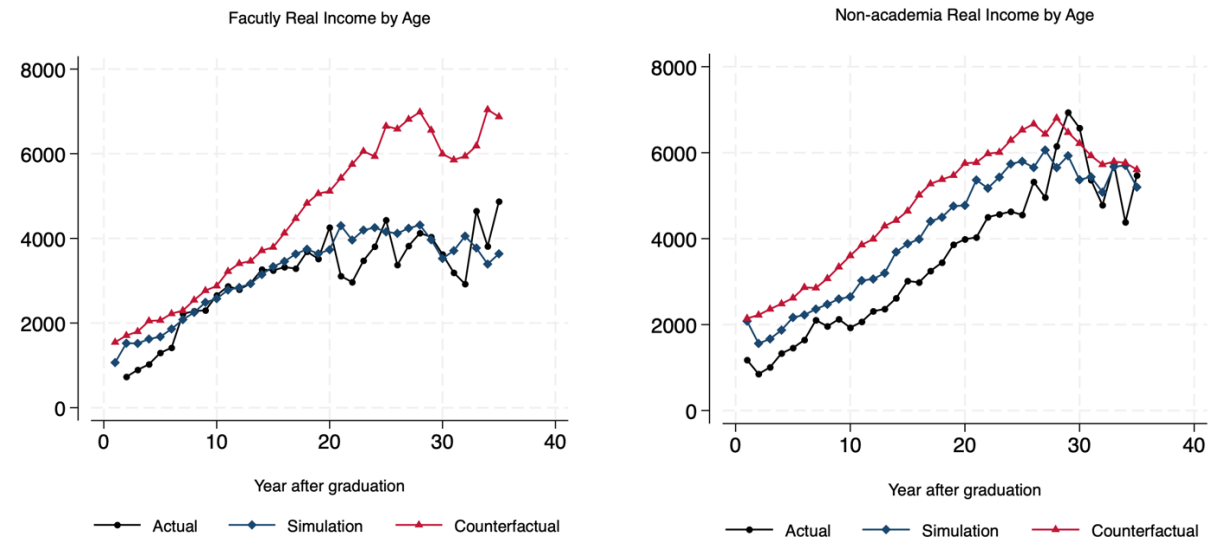


Figure 3. Actual, Simulated, and Counterfactual Age Profiles

Panel A



Panel B



Note: The Figure depicts actual, simulated, and counterfactual simulated (with no non-pecuniary preferences) shares and earnings profiles of engineering faculty (academia) and non-academia by years after graduation.

Table 1. 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 graduates ranked number one by academic achievement 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 the Engineering Department in Tokyo Imperial University who did or did not become faculty of the Engineering Department 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 the Engineering Department in Tokyo Imperial University who did or did not become faculty of the Engineering Department 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 the Engineering Department in Tokyo Imperial University who did or did not become faculty of the Engineering Department 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 the Engineering Department in Tokyo Imperial University who did or did not become faculty of the Engineering Department at some point between 1886-1939. Faculty divisions are defined as divisions in which graduates were hired as faculty for the first time.

Table 2. "Mincer" income regressions for top-ranked engineering graduates

VARIABLES	(1)	(2)
Years after graduation	0.099***	0.101***
	(0.008)	(0.008)
Years after graduation squared	-0.002***	-0.002***
	(0.000)	(0.000)
Imperial University faculty	0.036	0.149
	(0.065)	(0.092)
Employed in private sector	0.127**	0.033
	(0.064)	(0.116)
Years after graduation X Imperial University faculty		-0.007*
		(0.004)
Years after graduation X Employed in private sector		0.005
		(0.007)
Constant	6.775***	6.764***
	(0.064)	(0.059)
Year and graduation division FE	Yes	Yes
Observations	2,096	2,096
R-squared	0.495	0.499

Estimation method: OLS. The omitted category is public/military sector. Robust standard errors clustered at the individual level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3. Structural Estimation Results

Sectors	Academia	Private	Public/Military
		Wage Function	
Years after graduation	0.0897 (0.0061)	0.0682 (0.0088)	0.0837 (0.0064)
Years after graduation squared	-0.00186 (0.00019)	-0.00135 (0.00021)	-0.00171 (0.00018)
Constants	7.246 (0.0739)	7.460 (0.0796)	7.216 (0.0421)
Residual covariance:			
Academia	0.131 (0.046)		
Private	-0.243 (0.099)	0.190 (0.053)	
Public/Military	0.020 (0.009)	-0.105 (0.009)	0.0791 (0.020)
Scaling parameter (yen)		1,532 (404)	
		Mobility Cost Function	
Years after graduation	0.0893 (0.0205)	0 (normalization)	0.0981 (0.0221)
Years after graduation squared	-0.00239 (0.00062)	0 (normalization)	-0.00250 (0.00067)
Constants:	8.527 (0.311)	- (normalization)	8.461 (0.316)
		Non-pecuniary Utilities (yen)	
Average	-462 (313)	0 (normalization)	-422 (310)
Deviations:			
Type I	-772 (359)	0 (normalization)	-2,271 (365)
Type II	3,935 (398)	0 (normalization)	3,347 (383)
Type III	-2,131 (1201)	0 (normalization)	1,893 (819)
Type IV	-3,182 ()	0 (normalization)	-9,188
		Earnings Potential	
Type I	0.0706 (0.0542)	-0.455 (0.0550)	0.455 (0.0720)
Type II	-0.307 (0.0593)	0.298 (0.0591)	0.000 (0.0639)
Type III	-0.130 (0.0998)	-0.061 (0.0714)	-0.361 (0.0848)
Type IV	1.209 (0.127)	0.895 (0.098)	-0.478 (0.054)
		Share in Total	
Type I		0.325 (0.0424)	
Type II		0.294 (0.0540)	
Type III		0.294 (0.0480)	
Type IV		0.087 (0.0333)	

Note: These parameter estimates are very preliminary and are likely to change as the data are extended and the model refined. Non-pecuniary utility parameters have been normalized to zero in industry (private sector) for all types. Earnings potentials have normalized so that the weighted sum across all types sums up to zero in each sector. Standard errors are in parentheses and based on 100 block-bootstrap samples of the underlying sample.

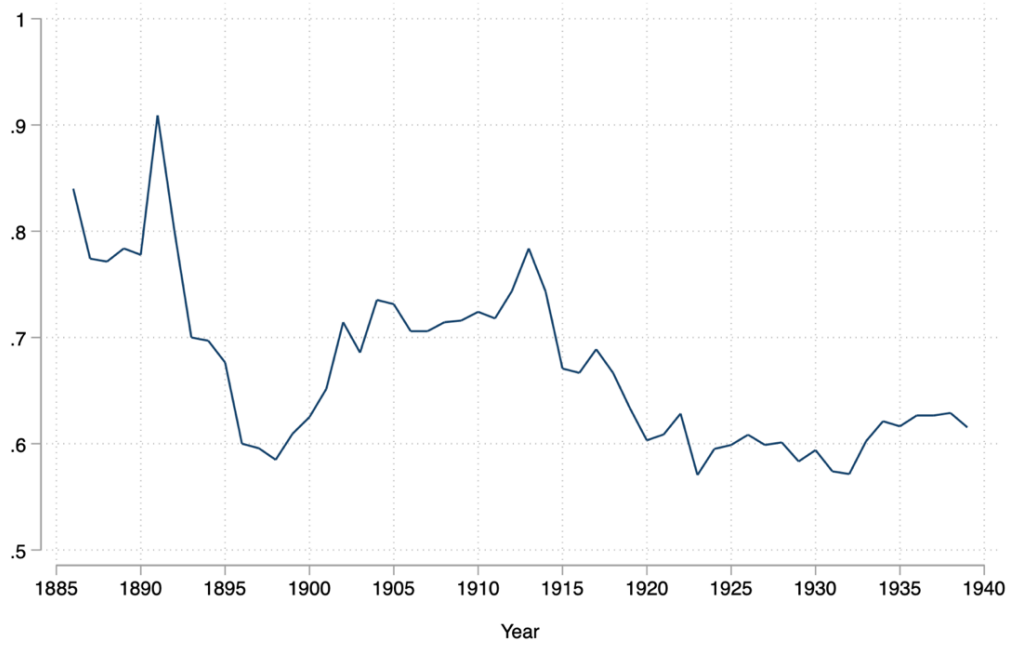
Table 4. Descriptive Statistics of Different Graduate Types

	Type I	Type II	Type III	Type IV	All
Education records:					
Top in high school (%)	26.9	42.0	24.7	17.4	29.6
Top in third year (%)	65.2	80.8	69.6	63.2	70.8
Top at time of univ. graduation (%)	100.0	100.0	100.0	100.0	100.0
High-tech divisions (%)	23.1	22.2	24.7	26.1	23.6
Outcomes:					
Imperial University faculty (%)	43.6	42.0	2.4	8.7	27.9
Real earnings (yen)	3,330.6	2,776.5	2,705.3	11,119.5	3,455.5
Imperial University earnings (yen)	3,649.3	2,015.4	3,107.7	13,001.1	3213.12
Observations:	108	81	85	23	297
Cohorts graduated before 1900	46	19	32	13	110
Cohorts graduated in 1900-1918	62	62	53	10	187

Note: Table 4 summarizes descriptive statistics of each unobserved type from the structural estimation. Real earnings are nominal earnings, adjusted for the consumer price index.

Appendix A. Figures and Tables

Figure A1. Share of Core Faculty in Total



Note: The figure presents the number of full and assistant professors at the engineering department in Tokyo Imperial University in each year, divided by the total number of faculty members in that year. Our calculations based on *Tokyo Teikoku Daigaku Ichiran*, 1886-1939.

Figure A2. Empirical Cumulative Distribution of High-School Graduation Ranking Among Core Engineering Faculty in Tokyo Imperial University

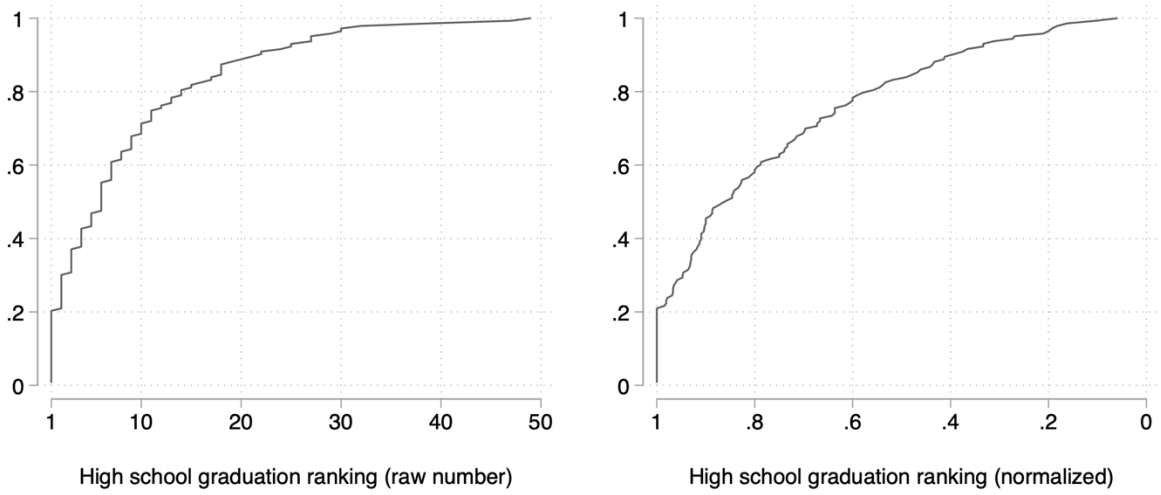
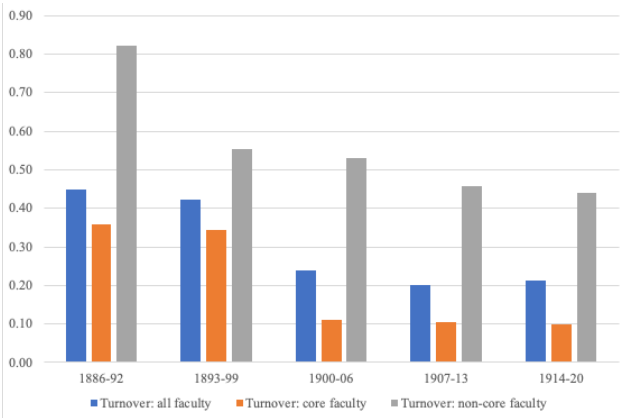
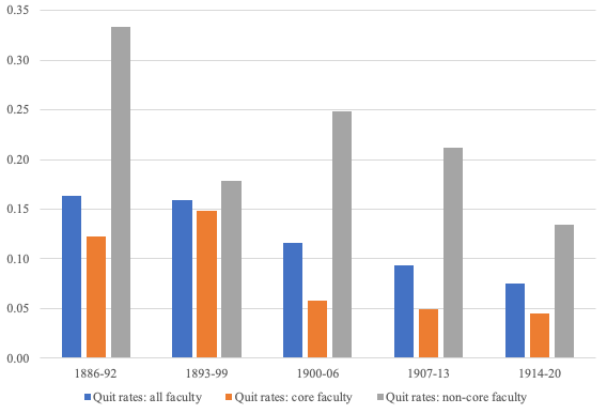


Figure A3. Turnover and Quit Rates Among Engineering Faculty

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.

Table A1. Descriptive Statistics on Engineering Faculty

Panel A. Number and fraction of faculty who are previous graduates

	Division										
	Civil Engineering	Mechanical Engineering	Naval Architecture	Electric Engineering	Architecture	Applied Chemistry	Metal and Mining	Ordnance	Explosives	Others	Total
Graduates of Eng. or Sci. Department	60 (88.24)	73 (93.59)	73 (90.12)	46 (100.00)	35 (87.50)	69 (93.24)	65 (91.55)	30 (62.50)	14 (82.)	22 (48.89)	487 (85.74)
Graduates of the other Departments	7 (10.29)	5 (6.41)	1 (1.23)	-	1 (2.50)	1 (1.35)	5 (7.04)	-	-	16 (35.56)	31 (5.46)
Non-graduates	1 (1.47)	-	7 (8.64)	-	4 (10.00)	4 (5.41)	1 (1.41)	18 (37.50)	3 (17.65)	7 (15.56)	50 (8.80)
Total	68	78	81	46	40	74	71	48	17	45	568

Panel B. Number and fraction of core and non-core faculty

	Division										
	Civil Engineering	Mechanical Engineering	Naval Architecture	Electric Engineering	Architecture	Applied Chemistry	Metal and Mining	Ordnance	Explosives	Others	Total
Core Faculty	48 (70.59)	32 (41.03)	39 (48.15)	20 (43.48)	26 (65.00)	44 (59.46)	41 (57.75)	13 (27.08)	7 (41.18)	14 (31.11)	284 (50.00)
Non-core Faculty	20 (29.41)	46 (58.97)	42 (51.85)	26 (56.52)	14 (35.00)	30 (40.54)	30 (42.25)	35 (72.92)	10 (58.82)	31 (68.89)	284 (50.00)
Total	68	78	81	46	40	74	71	48	17	44	568

Panel C. Faculty characteristics by graduates and non-graduates / by alma mater

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Graduates	Non-graduates	(1) - (2)	Graduates of Eng. or Sci. Department	Graduates of the Other Departments	(4) - (5)
Faculty tenure (years)	9.69 (9.13)	6.46 (6.18)	3.23** [3.36]	9.89 (9.26)	6.55 (6.06)	3.34** [2.87]
1{became core faculty}	0.52 (0.50)	0.29 (0.46)	0.24** [3.42]	0.53 (0.50)	0.45 (0.51)	0.07 [0.79]
Core faculty tenure (years)	6.40 (9.41)	1.84 (4.52)	4.56*** [5.99]	6.68 (9.60)	1.97 (3.25)	4.17*** [6.47]
1{sent to study/do research abroad}	0.16 (0.37)	0 (-)	0.16*** [10.00]	0.17 (0.38)	0 (-)	0.17*** [10.06]
# of years spent abroad (years)	0.40 (1.02)	0 (-)	0.40*** [8.94]	0.43 (1.05)	0 (-)	0.43*** [8.98]
# of faculty	518	50	-	487	31	-

Note: Panel A summarizes the number and fractions of graduates from the engineering department in the Imperial University, graduates from the other departments in the Imperial University, and non-graduates among faculty of the engineering department in Tokyo Imperial University between 1886 and 1939. Panel B summarizes the number and fractions of core and non-core faculty of the engineering department in Tokyo Imperial University between 1886 and 1939. "Core" faculty refers to professors and assistant professors, "non-core" faculty refers to lecturers and research assistants. We report these numbers by different divisions. The number represents unique individuals, and the fractions are reported in parentheses. Panel C summarizes the mean values of faculty characteristics across different groups as well as the mean differences between these groups. Standard deviations of the variables are reported in parentheses, and for the mean differences, t statistics are reported in brackets, *** $p < 0.001$: ** $p < 0.01$: * $p < 0.05$. In each panel, "graduates" mean individuals who graduated from one of the Imperial Universities.

Table A2. Cross-distribution of graduation and faculty divisions

Faculty division assignment by graduate division of Tokyo Imperial University

	Graduate Division									
Faculty Division	Civil Engineering	Mechanical Engineering	Naval Architecture	Electric Engineering	Architecture	Applied Chemistry	Metal and Mining	Ordnance	Explosives	Total
Civil Engineering	34 (91.89)	2 (3.12)	-	-	-	-	-	-	-	36 (12.54)
Mechanical Engineering	2 (5.41)	43 (67.19)	1 (2.78)	-	-	-	-	-	-	46 (16.03)
Naval Architecture	-	7 (10.94)	35 (97.22)	-	-	1 (2.27)	1 (2.94)	-	-	44 (15.33)
Electric Engineering	-	1 (1.56)	-	30 (96.77)	-	-	-	-	-	31 (10.80)
Architecture	-	-	-	-	21 (100.00)	-	-	-	-	21 (7.32)
Applied Chemistry	-	-	-	-	-	37 (84.09)	-	-	-	37 (12.89)
Metal and Mining	-	3 (4.69)	-	-	-	-	33 (97.06)	-	-	36 (12.54)
Ordnance	-	6 (9.38)	-	-	-	2 (4.55)	-	13 (100.00)	1 (14.29)	22 (7.67)
Explosives	-	-	-	-	-	4 (9.09)	-	-	6 (85.71)	10 (3.48)
Others	1 (2.70)	2 (3.12)	-	1 (3.23)	-	-	-	-	-	4 (1.39)
Total	37	64	36	31	21	44	34	13	7	287

Note: The table shows the number and fraction (in parentheses) of graduates from the Engineering Department of Tokyo Imperial University who become faculty of the Engineering Department of Tokyo Imperial University between 1886 and 1939 by their graduation and faculty divisions. Faculty divisions are inferred from the courses faculty taught and assigned to each faculty member based on which division they were affiliated with most of their tenure.

Table A3. Descriptive Statistics of Engineering Graduates

Graduate characteristics by faculty and non-faculty / by core faculty and non-core faculty

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Faculty	Non-faculty	(1) - (2)	Core Faculty	Non-core Faculty	(4) - (5)
University graduation ranking (normalized)	0.79 (0.28)	0.49 (0.31)	0.30*** [16.67]	0.87 (0.21)	0.70 (0.31)	0.17*** [5.05]
High-school graduation ranking (normalized)	0.69 (0.28)	0.52 (0.30)	0.18*** [9.19]	0.77 (0.24)	0.61 (0.30)	0.16*** [4.51]
1{graduated from a top high school}	0.57 (0.50)	0.40 (0.49)	0.17*** [5.45]	0.61 (0.49)	0.52 (0.50)	0.09 [1.61]
1{earned a doctoral degree}	0.41 (0.49)	0.04 (0.21)	0.37*** [12.71]	0.59 (0.48)	0.22 (0.41)	0.37*** [7.00]
1{hailed from Tokyo, Osaka, or Kyoto}	0.36 (0.48)	0.24 (0.43)	0.12*** [4.12]	0.35 (0.48)	0.37 (0.49)	0.02 [0.33]
1{at least one patent}	0.39 (0.49)	0.17 (0.38)	0.22*** [7.44]	0.42 (0.50)	0.36 (0.48)	0.06 [0.95]
Observations	287	3948	-	150	137	-

Note: The table summarizes the mean values of graduates' characteristics across different groups as well as the mean differences between these groups. Standard deviations of the variables are reported in parentheses, and for the mean differences, t statistics are reported in brackets, *** $p < 0.001$: ** $p < 0.01$: * $p < 0.05$. Faculty are individuals who were faculty of the Engineering Department of Tokyo Imperial University at some point between 1886-1939. Core faculty means faculty who became full or assistant professor of the Engineering Department of Tokyo Imperial University at some point between 1886-1939, and non-core faculty are those who never became core faculty.

Table A4. 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).

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 A5.

Share of engineering faculty among all graduates and top graduates by graduation years

Share of engineering faculty among engineering graduates			
All cohorts until 1918: Tokyo Imperial University	0.071	Of which: Top graduates	0.322
All cohorts until 1918: all Imperial Universities	0.101		0.407
Graduated before 1900: Tokyo Imperial University	0.113		0.292
Graduated before 1900: all Imperial Universities	0.138		0.381
Graduated after 1900: Tokyo Imperial University	0.059		0.338
Graduated after 1900: all Imperial Universities	0.091		0.422

Table A6 Raw Data Classification

	Academia: High Earners	Academia: Low Earners	Non-Academia
Education records:			
Top in high school (%)	37.5	56.3	25.4
Top in third year (%)	69.0	83.9	69.4
Top at time of univ. graduation	100.0	100.0	100.0
High-tech divisions (%)	25.0	34.4	22.4
Outcomes:			
Imperial University faculty (%)	100.0	100.0	0.0
Real earnings (yen)	4,524.4	2,104.3	3,550.4
Imperial University earnings	4,402.9.	2,159.9	-
Observations:	32	32	205
Cohorts graduated before 1900	26	4	73
Cohorts graduated in 1900-1918	6	28	132

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. Real earnings are nominal earnings, adjusted for the consumer price index.

Appendix B. More Details about the Data Development Procedures

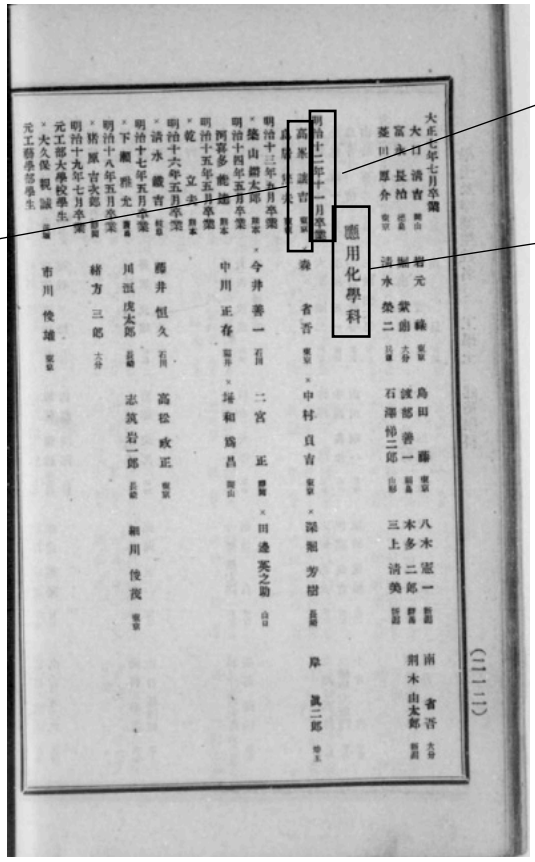
B.1. Annual Calendars of Imperial Universities (*Ichiran*)

Each Imperial University in Japan published annual Calendars (such as *Tokyo Teikoku Daigaku Ichiran*, also called *Tokyo Teikoku Daigaku Yoran* in some years) which are available in open access through the National Diet Library Digital Collections (https://dl.ndl.go.jp/en/). Those calendars have the section listing all graduates' names in all prior cohorts. The list of graduates starts with the first graduation cohorts from their predecessors: the 1877 cohort from University of Tokyo for science and the 1879 cohort from *Kobu Daigakko* for engineering. Importantly, in Tokyo Imperial University Calendars, in particular, up until 1918 the students were listed 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. As shown in Figure A1, the graduate names are listed for each science or engineering division and each graduation cohort. The order of the graduates is based on their graduation rank for Tokyo Imperial University graduates until 1918 cohorts, and Japanese alphabetical orders for other graduates. For example, Figure A1 shows that Jokichi Takamine (who discovered adrenaline) graduated the applied chemistry division of Tokyo Imperial University at the top of the class of six people in 1879.

We digitized the data on all the graduates in Science and Engineering from the first graduation cohorts in the late 1870s and until the 1920 graduation cohorts listed in those calendars. These data were then matched with Annual Alumni Surveys of Imperial Universities' Graduates (described in the next section) to follow the graduates' employers and addresses updated in those surveys on an annual basis. The most challenging part of the matching process was to keep track of name changes that were common in Japan at that time, mostly due to frequent cases of adult adoption. [17] The writing of characters in the names also varies from source to source, which presented another challenge. The list of all different names and name writing variations was created and shared with the current authors by Shotaro Yamaguchi.

[17] 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 *Shimeiroku* which were used to identify such cases. Ssources used to track name changes include also *Imperial University Calendars*, High-school Registries (*High-school Calendars*), Japan Doctors Index (*Dainihon Hakushiroku*) and other sources.

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

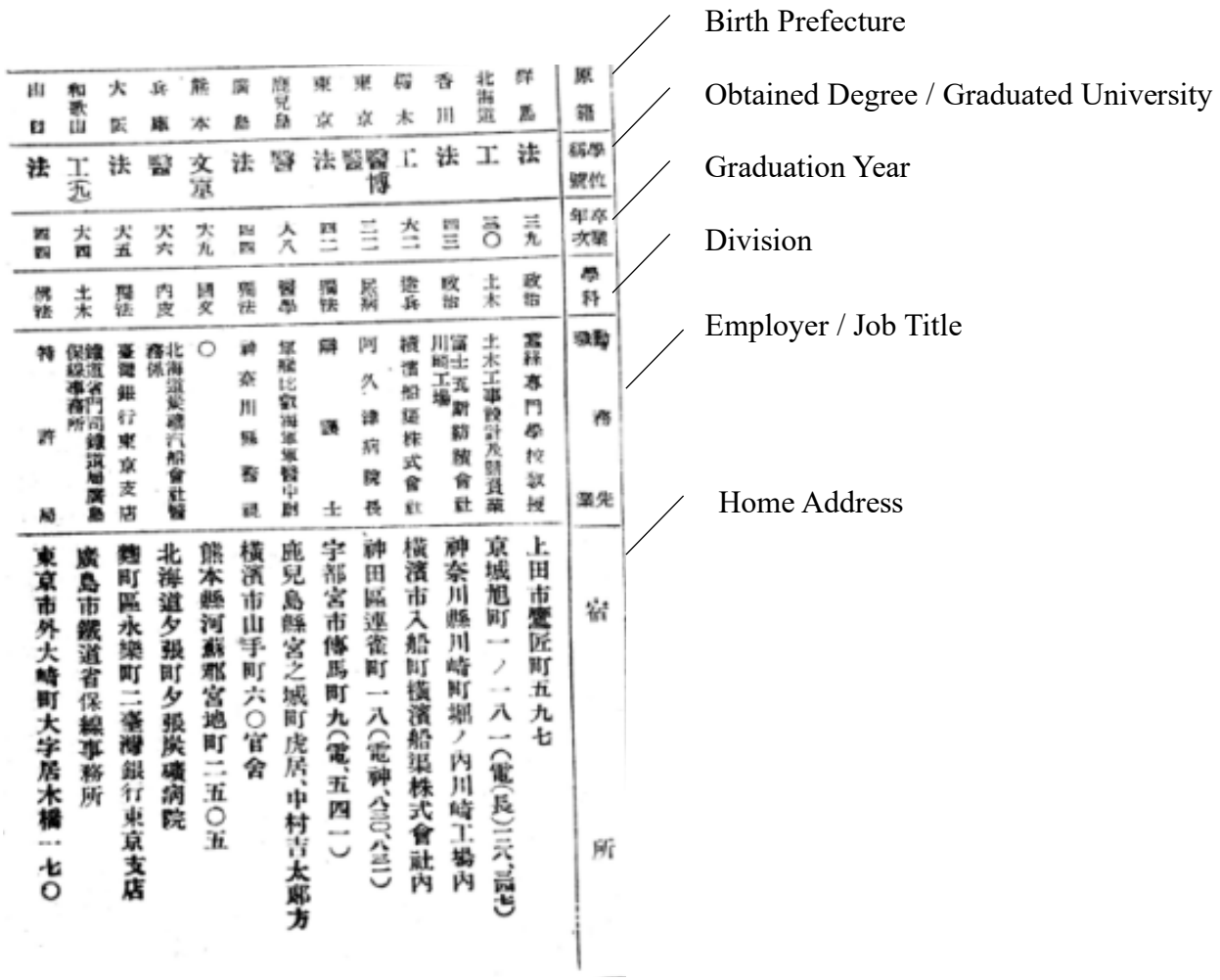


Source: Annual Catalog of Tokyo Imperial University (*Ichiran*) Taisho 7 (1918).

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

The alumni association of Imperial Universities, *Gakushikai*, annually publishes alumni lists containing information about addresses and workplaces for each graduate belonging to the association. Digital images of those surveys for every year from 1890 to 1940 (with two missing years, 1893 and 1894) were provided to us by *Gakushikai*. We obtained information for all the identified graduates who were found in these lists. Even though membership in the association was voluntary, more than 90% of all graduates joined it, and for all of them we have information about their addresses and workplaces. Figure A2 shows how the information for each graduate appears in this list. Among those information, employer / job title and home address were annually updated while the other information was unchanged across the periods.

Figure B2. A sample page of alumni lists in 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), our project is the first one to use *all* the data available on science and engineering graduates from those surveys (comprising about 90% of all graduates). As mentioned, people would change names due to adult adoption, so we kept track of those instances that were recorded in separate sections of the Alumni Surveys. Furthermore, as

we worked on cleaning and verifying the data, there were multiple instances where survey information was updated with a lag and more exact information was available from published biographies and other reliable historical sources. In such cases, we updated the employer/address information from the surveys by the corrected information we found in other sources, but we also kept the original survey data, so that it would be possible to see which updates we introduced. We also recorded the sources on which we based our updates. The work on triangulating and verifying the data from alumni surveys is ongoing with the participation of Shotaro Yamaguchi and the two present coauthors. While the surveys themselves may eventually be fully digitized, the verification and updating that we are doing requires manual checks and will significantly improve the quality of the data that can be obtained from the surveys themselves. Once we determine that our work has been completed to a reasonable degree, we will make the updated Alumni Surveys data public and invite other scholars to contribute to verifying and correcting it even more.

B.3 Matching with Patent Publication Records

This project is the first one to create the bridge between Imperial Universities' alumni and patent data. The collaborating team in Japan, comprised of Hiroyasu Inoue, Kentaro Nakajima, Tetsuji Okazaki, and Yukiko Umeno Saito constructed a historical database of patent specification records. The original records of every patent specification (from the first patent based on the Patent Law) are preserved by the Japan Patent Office and their image data are available in 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 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[18]. The address data were converted to the geographic divisions as of 2015 based on the municipal transition history (https://uub.jp/upd/).[19]

Technology classes appearing in the original patent specifications are based on the classifications at the time when the patent was registered, but the classification scheme was

[18] The detailed process of digitizing Japanese historical patent records is described in Inoue et al. (2020) (in Japanese).
[19] As Inoue et al. (2020) mention, the Japan Patent Office in Tokyo was destroyed by the Great Kanto Earthquake in 1923, and all the documents until that time were lost. The patent information available today for the years before 1923 was organized by re-collecting documents that were scattered outside Tokyo, such as at the regional branch offices. Therefore, for a considerable number of patents before 1911, bibliographic information is incomplete.

updated several times during our observation period. For consistency, they used the version released in 1948 using 135 technology classes since the Japan Patent Office reclassified all prior patents based on this new classification scheme and published those correspondence tables in the Patent Classification Catalogue (*Tokkyo Bunrui-betsu Somokuroku*) in 1958 (Japan Patent Office, 1958).

The digitized patent records above were shared by the Inoue et al. collaborative team with Yamaguchi and Braguinsky, who then undertook the task of name-based matching of patent inventors and University graduates. As mentioned above, different combinations of different forms 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 *Ichiran* of Imperial Universities, *Ichiran* of public high schools, Japanese Personnel Inquiry Records (*Jinji Koushinroku*), Imperial University Graduates Directory (*Teikoku Daigaku Shusshin Meikan*) 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 one and the same person (the fraction of cases dropped through this manual check was about 10 percent of the total number of initial matches).[20] In the end, we have 7,719 patents matched to 1,451 unique inventors who were also Imperial University graduates in Engineering or Science after this manual data cleaning process.

The key challenge in our context is how to assess the productivity of inventors in terms of quality of inventions, as widely-used measures such as patent citation data are not available. Instead, we use the data from the Imperial Inventor Directory (*Teikoku Hatsumeika Meikan*) published by the Osaka Institute of Invention and Innovation, which compiled the most impactful inventions patented until 1935. We also matched the names and patent contents of University-educated Japanese inventors in our sample with names and patents in google patents and identified 200 inventors who had at least one patent applied for and granted outside of Japan (mostly in the United States and Great Britain, but also in France, Germany, Switzerland, and so on). Those inventors were granted 924 patents, some of which continue to be cited. We use such global patents, matched with their Japanese patents prototypes as another quality measure.

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

References

Inoue, H., Okazaki, T., Saito, Y., & Nakajima, K. (2020), "Senzenki Nihon no Innovation Katsudo: Tokkyo Joho no Denshika niyoru Approach" (*Innovation Activities in the Prewar Japan: Digitization of Patent Records*, in Japanese) RIETI Policy Discussion Paper Seriges 20-P-012.

Sawai, M. (2020). "Senkanki-ni okeru Gijutsusha-no Kigyou-kan Idou." *Nanzan Daigaku Kiyou "Academia" Social Sciences,* 18: 1-20.

Uchida, H. (1979). "Meiji Kouki Minkan Kigyou-no Gijutsusha Bunpu." *Keieigakushi*, 14(2): 1-29.

Uemura, M. (2017a). "Kindai Nihon-ni okeru Kougakushi-no Shouchou, Chihouchou, Minkan Bumon-kan-no Idou." *Shakai Kagaku*, 47(3): 1-41.

Uemura, M. (2017b). "Kindai Nihon-ni okeru Kougakushi -no Rikukaigun, Minkan Bumon, shoucho, Kyouiku Kikan-kan-no Idou." *Shakai Kagaku,* 47(4): 29-66.

Yamanushi, Masayuki. (1962) *Kazoku-ho Ronshu (Collection of Papers on Family Law*, in Japanese*). Horitsu Bunkasha*.

Appendix C. Illustrative Cases

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

Difficulty in retaining talent: Ichisuke Fujioka

While the Imperial University was generally able to attract and retain top talent, that was not always the case, especially earlier in our sample period. 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 a case in point. He was appointed 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 at that time, 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 digitized by the authors, available upon request), while Kyozo Kikuchi, who graduated two years later than Saito as number two in the class of three, was paid 100 yen per month (1200 yen annualized) as the chief engineer of Hirano Spinners (Hirano Spinners Company Report #1 digitized by the authors, available upon request). Given Fujioka's 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 1200 yen, the salary offered by the utility company would have been 50% higher than the salary offered by the University.

Rewarding an innovator and building complementary assets: Kyoji Suehiro

In Table C1 we utilize the biographical knowledge about specific events mapped into the career timeline of Kyoji Suehiro to illustrate how invention translated into higher earnings for engineering faculty in some detail. Suehiro graduated from the Naval Architecture division of the Engineering Department in 1900 and joined the engineering faculty in 1902 after a one-year stint

with Mitsubishi Shipbuilding Co. His income in 1902-1905 corresponds to the salary schedule for an assistant professor in those years, inclusive of service allowance (Table A4 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. After returning from the sabbatical in 1912, 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), and he also applied for the patent related to this technology 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 1913-1914, 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 A5. 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 at the helm of Mitsubishi Shipbuilding Research Institute, Suehiro remained a consultant for Mitsubishi Shipbuilding for the rest of his career and all his subsequent patents were assigned to Mitsubishi Shipbuilding. He also was appointed the director of the Earthquake Institute established by Tokyo Imperial University in November 1925 and served in this position until he passed away in 1932. As can be seen from Table C1, this complementary asset appears to have contributed to further increase in his income which was way above the standard salary of a senior engineering faculty professor throughout the 1920s. Notably, his income was especially high in 1923-24, the years immediately after he won the Imperial Academy Prize. All in all, this example clearly shows the pattern where a star inventor would earn significant extra income from the private sector based on technology transfer and consulting, while staying as full professor at the Engineering Department. It is also suggestive of high pecuniary rewards accruing to those who won prestigious awards.

Building complementary assets: Mastatoshi Okochi

Masatoshi Okochi (1878-1952) graduated at the top of his cohort from the ordnance division in 1903 and was immediately hired as a lecturer in the engineering department upon graduation, becoming assistant professor the next year and promoted to full professor in 1911 immediately following a two-year sabbatical in France. A prolific inventor, Okochi had 73 domestic and 14 global patents over his illustrious career. In 1921 he was appointed to be the director of *Riken*, the Institute of Physical and Chemical Research (currently a National Research and Development Agency, but launched as a private institution in 1917 and modeled after the Kaiser Wilhelm Society in Germany). In this capacity he implemented a system of independent laboratories each led by a Chief Scientist who would also be a prominent professor in his field at the Imperial University, given autonomy to manage research topics, personnel and budget. This resulted in an explosion in innovative by University faculty who became affiliated with *Riken.* Specifically, thirty two 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 0.7 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 collaborators at *Riken* (details are available upon request). Indeed, *Riken* was so successful in generating industry technologies that it generated a whole industrial group of companies (Riken Industrial Group) which included high-tech firms, such as Ricoh, which still survive to the present day. Alongside with the afore-mentioned Institute of Aeronautics and other similar institutes affiliated with the University, *Riken* provided a vehicle through which university engineering and science faculty could develop industrial technologies, patent them and reap rewards, all while working their academic jobs at the same time.

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

Notes: His research that led to the 1912 patent (also patented globally) was awarded the 1922 Imperial Academy Prize (most prestigious academic prize in Japan). Helped found Mitsubishi Shipbuilding Research Institute in 1918 and was its director in 1919-20. Stayed as Mitsubishi Shipbuilding consultant. All patents from 1926 assigned to Mitsubishi Shipbuilding. Became first director of the Tokyo Imperial University Earthquake Research Institute in Nov. 1925 and stayed in this position until he passed away in April 1932.