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Invention by College Graduates in Science and Engineering during Japan's Industrialization*

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Abstract

During Japan's industrialization from the late 19th to the first half of the 20th century, the adoption of foreign technologies was increasingly complemented by domestic inventions, while the role played by college-educated scientists and engineers in inventions has not been examined. We match demographic, domicile and job information of Imperial University and Technical College science & engineering (S&E) graduates from the onset of Japanese higher S&E education with patent application records in the Japanese Patent Office during the period 1885-1940 to identify who were granted patents, when and where they invented, and how such patterns changed over time. We find that the presence of S&E graduates among inventors increased over time. The likelihood of becoming inventors significantly varied across schools and divisions. Also, Imperial University graduates tended to produce inventions of higher quality, and their inventions were more concentrated in regions where economic activities were intense.

Keywords: Industrialization, Invention, Patent, Science and Engineering Education
JEL classification: O30

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1. Introduction

Early British inventors at the dawn of industrial revolution "tended to be "tinkerers" without much formal technical schooling" (Mokyr, 1992, p. 245). After about 1850, however, "deeper scientific analysis was needed, [and] German and French inventors gradually took the lead" (*ibid.*) In particular, technical schools established in many European countries in the second half of the 19th century amazed the British and played a central role in those countries catching up to Britain (Mokyr, 1992, p. 263). As Japan embarked on the same catch-up process later in the 19th century, it faced a similar need and answered it also through establishing a system of higher science and engineering (S&E) education to foster the conditions for technological catch-up (Miyoshi, 2005; National Institute for Education Research, 1973).

While these historical "macro" facts are well-known, there has been a resurgence of interest in recent years in examining more specifically the role that S&E-educated human capital had played in technological inventions contributing to accumulating the knowledge stock and transforming industrial structure (e.g., Maloney and Caicedo, 2020). However, to the best of our knowledge, due to lack of suitable data, no prior studies have been able to link inventors to individual-level university/college graduates' employer and domicile records as well as their demographic information. Therefore, the role played by university- and college-educated scientists and engineers, especially during a country's industrialization period still remains understudied, at least in large data sets. In this paper, we utilize unique archival data from Japan that allow us to combine patent records with demographic, domicile and job information of S&E university and college graduates from the onset of Japanese higher S&E education. Specifically, we look at which of them become inventors, when and where they invent in their career trajectories, and how do such patterns change over time, especially as industries and higher education coevolve in a country's industrialization.

We focus on Japanese industrial revolution starting from the second half of the nineteenth century. This was the period that witnessed the transition from artisan production to large-scale mechanized manufacturing, and an enormous transformation of the industrial structure (starting from light industry, as is typical in early industrialization, and moving to add heavy and chemical industries). At the same time, both S&E higher education system and intellectual property rights system (patent law) were established for the first time and then grew and evolved. Through the whole period, Japan's remarkable ascension from a poor backward to a modern industrial nation stands out as the first such case outside of Western Europe and its offshoots in North America and

Australia. Importantly, to achieve such growth, slavish imitation of foreign technologies was not sufficient. The adoption of foreign technologies was significantly complemented by the inventions of indigenous technologies by domestic inventors, and it would not have been possible without educated science and engineering talent.

We begin by describing the procedure through which we constructed the novel database matching the *universe* of patent publication records from 1885 (the year the first patent law was enacted) until 1940 to the *universe* of Imperial Universities graduates from S&E departments (*Rigakushi* and *Kougakushi*) as well as graduates of Technical Colleges (*Koto Kogyo Gakko*), starting from the very first cohorts in 1877-79 and until the 1920 graduating cohort. In other words, we obtain detailed individual-level data on the patenting activities of *all* highly educated scientists and engineers during the period. Since there are no patent citation data available for the period of our examination, we identify patents that made it to a prestigious catalogue, the Imperial Inventor Directory (*Teikoku Hatsumeika Meikan*) to measure their relative impact.

We are not the first to document invention patterns in a country's early industrialization periods.[1] Akcigit et al. (2017) match several decennial U.S. Censuses data to patent (USPTO) data to examine various characteristics of inventors. One of their key findings is that "[w]hile education seems to be an important determinant of becoming an inventor, the effect is particularly strong at the college degree level." (p. 32) They cannot distinguish, however, between STEM and non-STEM college education and the data are limited to one cross-section using the 1940 U.S. Census.

Recent scholars strive to identify the causal effect of higher education on local inventions (Aghion, et al., 2009; Furman and MacGarvie, 2007; Hausman, 2020; Kantor and Whalley, 2014; Kim, 2020; Toivanen and Väänänen, 2016). Yet, those studies fail to capture the "direct path" from higher education to inventions: individuals benefiting from their affiliation to universities are more likely to produce inventions. Andrews (2020) more directly identified patent inventors who were alumni or faculty members of a college by matching inventor names with historical college yearbooks and to U.S. population census data for the years 1940 and earlier. Bianchi and Giorcelli (2020) match the list of high school graduates in Milan to Italian patent records and find that individuals who received a university S&E degree not only likely produce more inventions in S&E-oriented fields, but also more likely sorted into innovative occupations. Our paper is in line with

[1] Pioneering studies include Akcigit et al. (2017), Hanlon (2015), Lamoreaux and Sokoloff (1999), Moser (2005), Moser and Voena (2012), Nicholas (2010, 2011a, 2011b, 2013), Sokoloff (1988), Sokoloff and Khan (1990).

these emerging research streams, while further complemented by individual-level employer and domicile information from annually updated graduates' alumni lists and college registers. To the best of our knowledge, an exercise where the universe of all university- and college-educated scientists and engineers are matched to their patents and complemented by the annual-based panel data on their job and domicile histories has never been attempted before. Uniquely, as Japan developed from a feudal society to an industrial power during the period covered by out data, not just the economy, but the higher education system itself was evolving—expanding its scale, widening and granulating education fields, all of which contributed to the evolution of the sectoral and geographical distribution of university-educated inventors and affected the direction and the rate of invention.

Limiting to Japan's historical context, some broad patterns of the domestic inventive activity during its industrialization have been noted before (e.g., Nicholas, 2010; 2011a; 2011b). But again, the role of S&E education in this process has not been examined even at the aggregate level, to say nothing of the individual inventor level. Similarly, while there are studies by Japanese historians of the allocation across sectors of degreed engineers in Japan at that time[2], those studies do not distinguish between inventors and non-inventors and the scope and time periods of their observations are also constrained. As mentioned, our unique database covers the universe of individuals with science and engineering degrees from all Imperial Universities and Technical Colleges, their patented inventions, and job and domicile histories.

2. Historical Background

After the Meiji Restoration, one of the primary goals of the new Japanese government was to rapidly absorb frontier technologies from Western countries and create modern industries. The government realized the importance for this purpose of building a stock of indigenous highly skilled human capital in science and engineering which had been all but non-existent in Japan prior to the Meiji Restoration. The government education policy announced in 1868 (the first year of the Meiji era) is summarized in three points: to diffuse primary education, to establish higher education institutions to produce instructors, and to promptly absorb foreign cutting-edge technologies (Kaigo, 1968).

[2] The studies include Abe and Nakamura (2010), Iwata (2008), Sawai (2012), Uchida (1979; 1988a; 1988b), Uemura (2018).

The government recognized the need for S&E education at the very beginning and had gradually refined its systems[3]. It first created the basic design of a new education system under its administration and announced the Education System (*Gakusei*) in 1872. According to *Gakusei*, the education system was to be composed of three tiers: primary (*shogaku*), secondary (*chugaku*) and tertiary (*daigaku*) education. Two provisions added to *Gakusei* in 1873 emphasized the need to establish professional education (e.g., law, science, and engineering) at the tertiary level. Accordingly, the government launched the tertiary-level education in law, science, engineering, mining, and liberal arts at *Kaisei Gakko*, whose origin was *Bansho Shirabesho* (literally, the Institute for Investigating Barbarian Books) founded by Tokugawa Shogunate before the Meiji Restoration. In 1874, *Kaisei Gakko* was renamed *Tokyo Kaisei Gakko* and reorganized to have four specialized departments: law, engineering, chemistry and physics. In 1877, *Tokyo Kaisei Gakko* was merged with *Tokyo Igakko* (Tokyo Medical School) to be the University of Tokyo composed of four departments: law, science (including engineering), literature, and medical science.

As a rather separate stream, the government launched engineering education led by the Ministry of Industry in the beginning of the 1870s. The government paid special attention to increasing the stock of formally trained domestic engineering human capital, in part because it was too costly to invite and keep hiring a large number of foreign engineers (*O-yatoi Gaikokujin*), which both the government and private companies had to rely upon at the start of industrialization. Thus, as the government established the Ministry of Industry in 1870, it also opened an engineering school *Kogakuryo* operated by the same Ministry in 1871. *Kogakuryo* originally had seven divisions (applied chemistry, civil engineering, construction, electric engineering, mechanical engineering, metallurgical engineering, mining engineering), while shipbuilding engineering was later added in 1882. All the instructors were initially from foreign frontier countries, such as Germany, Britain, and the U.S. *Kogakuryo* then became *Kobu Daigakko* in 1877, and its operation was transferred to the Ministry of Education in 1885. Following the Imperial University Law (*Teikoku Daigaku Rei*) in 1886, *Kobu Daigakko* was merged with the engineering department of the University of Tokyo and the whole university was reorganized into Tokyo Imperial University.

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[3] The early history of tertiary education in science and engineering until Tokyo Imperial University was born, which is described below, is based on *Tokyo Daigaku Hyakunen-shi (Tsu-shi). (The 100 years of the University of Tokyo (Overview of History), in Japanese)* published in 1987.

Until the second Imperial University was established in Kyoto in 1896, Tokyo Imperial University was the only institution that granted graduating students university degrees. Kyoto Imperial University also had both science and engineering departments, though their scope was narrower[4]. Two other universities were established in Sendai in 1907 (Tohoku Imperial University) and in Fukuoka in 1911 (Kyushu Imperial University)[5]. Thus, as of 1920 there were four universities granting either or both of science and engineering degrees. The divisions offered in each University and the years of their first cohorts are summarized in Table 1. While engineering education at the Imperial Universities was initially primarily intended to produce engineers working for the government, scholars have noted that many of them did not stay in government for long and went to the private sector, supplying S&E talent also to various industries and leading to the emergence of some great firms. Indeed, our sample of University engineering graduates include founders of Toyota, Nissan, Hitachi, NEC, Toshiba, and many other currently existing and globally competitive firms.

Another major supplier of engineers was Technical Colleges (*Koto Kogyo Gakko*) administrated by the Ministry of Education. In contrast to engineering education at the Imperial Universities primarily focused on producing engineers working for the government, or technocrats, Technical Colleges aimed at generating middle-class engineers, who were supposed to bring trained engineering skills into practice and manage lower-class engineers (with no formal technical education) and blue-collar workers at production facilities (Tokyo Institute of Technology, 1985). Cultivating teachers and trainers working for middle-level engineering schools was another major goal of these Technical Colleges (Miyoshi, 2005). The first Technical College was launched in Tokyo in 1881.[6] While Tokyo Technical College initially had only applied chemistry and mechanical engineering divisions, it expanded later into diverse areas such as ceramic engineering, construction, dyeing, electric engineering, industrial design, spinning and the like. Eight more Technical Colleges

[4] At the beginning Kyoto Imperial University had only four divisions (chemistry, math, physics, science) in the science department and five divisions (applied chemistry, civil engineering, electric engineering, mechanical engineering, mining engineering) in the engineering department.

[5] Tohoku Imperial University opened the science department in 1911 (its first cohort graduated in 1914) and merged Sendai Technical College to launch the engineering department in 1912. That engineering department became independent again in 1921. Throughout this paper, we treat graduates from the engineering department operated by Tohoku in 1912-1920 as Sendai Technical College graduates. Kyushu Imperial University had the engineering department from the beginning, while it didn't have the science department until 1939.

[6] The school was originally named Tokyo Craftsman School ("*Tokyo Shokko Gakko*"). The name caused confusion because despite its intention to replace traditional craftsmanship by science-based engineering education, it gave the impression of taking over craftsmanship (Amano, 2009). For such reason it was renamed Tokyo Technical School ("*Tokyo Kogyo Gakko*") in 1881, and further renamed Tokyo Technical College ("*Tokyo Koto Kogyo Gakko*") in 1890.

had been established before 1915, geographically dispersed to give access to wide areas of the country[7]. Table 2 summarizes engineering divisions offered in each Technical College and the years of their first graduation cohort.

As the first engineering school *Kogakuryo* was launched by the Ministry of Industry, patent system began to emerge almost around the same time. Japan's patent system originates from the Patent Ordinance (*Senbai Ryakukisoku*) established in 1871, which was suspended a year later due to the lack of funds to hire a large number of foreign experts for patent examinations (Ministry of International Trade and Industry, 1964, p. 72). Although there were some patent applications submitted to the government under the Patent Ordinance, they ended up not being granted.

In 1885, a new legal framework, the Patent Law (*Senbai Tokkyo Jyorei*) was enacted. In addition, the government issued the Patent Procedure (*Senbai Tokkyo Tetsudsuki*), which prescribed that a patent application should be filed with the Ministry of Agriculture and Commerce by a local official, and how applications, specifications, and drawings of claimed technologies should be described in an application. A patent specification was supposed to contain (1) a general description of the object and nature of an invention, (2) an explanation for a drawing (in case it was attached), (3) a detailed description of production of the invented technology, its structure and composition, and the way to use it, (4) the technological area of the invention, and (5) the societal status[8], home address, and name of the inventor (Japan Patent Office 1955, p. 46). Initially there were no examinations, but after the amendment of the Patent Law in 1889 patent examiners began to grant them.

3. Data

3.1 Imperial University graduates

Our primary data source for Imperial Universities' graduates data is the catalogs of the Imperial Universities (*Ichiran)*. These were published annually and recorded the list of graduates by the departments/divisions they graduated from, year and month of graduation, and birth prefectures.[9]

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[7] The cities where Technical Colleges were build were Osaka, Kyoto, Nagoya, Kumamoto, Sendai, Yonezawa, Akita, and Kiryu (in the chronological order of establishment). Among them, the college in Akita was specialized in mining engineering and the college in Kiryu was specialized in Dyeing and Spinning.

[8] Until the enforcement of the Constitute of Japan in 1947, there was a societal class hierarchy composed of *Kazoku* (noble), *Shizoku* (samurai ancestor), and *Heimin* (commoner).

[9] While there is no gender information, there were no females admitted to Imperial Universities until Tohoku Imperial University admitted the first three female students in 1913. No female graduate could be matched to the patent database so our sample consists of all males.

For each of the four universities (i.e., Tokyo, Kyoto, Tohoku, and Kyushu) we collect the data on all of the graduates in the science and engineering departments from their first cohort until the cohort of 1920. The total number is 7,740 graduates.[10]

We next combine the list of graduates obtained from *Ichiran* with University alumni lists (*Gakushikai Kaiin Shimeiroku; hereafter, Shimeiroku*) published by *Gakushikai*, which is the association of the Imperial University alumni. The University alumni lists compile self-reported employers and address information for each individual graduate on an annual basis[11]. Since *Gakushikai* is a voluntary association, not all Imperial University graduates were its members but a large majority was. We obtained employer and domicile information for at least one year for 90.9% (1,367 out of 1,504) of identified university graduates-inventors. We supplemented the information from *Shimeiroku* by triangulating across various archival sources, including Japanese Personnel Inquiry Records (*Jinji Koushinroku*), Japan Doctors Index (*Dainihon Hakushiroku*), Japan Industrial Handbook (*Nihon Kogyo Yokan*), and Imperial University Graduates Directory (*Teikoku Daigaku Shusshin Meikan*). We also used this triangulation to identify and adjust the timing of job/domicile changes in cases where such changes were reported with a lag in *Shimeiroku*.

3.2 Technical College Graduates

Similar to University graduates, we also obtain data on Technical Colleges' graduates from annual catalogs (*Ichiran*) published by each college. In contrast to Imperial Universities, these catalogs contain annually-updated graduates' employer and domicile information, so they are self-contained for our purposes. The time periods the information is available varies across schools[12].

3.3 Matching with Patent Publication 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/). We digitized bibliographic information recorded in all patent specifications for patents granted between 1885 and 1940 (around 126,000

[10] We include in our sample the graduation cohorts (1877-1886) from *Koubu Daigakko*, which is the predecessor of the School of Engineering at Tokyo Imperial University.
[11] The detailedness of address and employer information varies across individuals. Some individuals reported their employer and its branch as well as their job titles, while others reported only addresses.
[12] The observable period for each school is summarized in Table 3.

patents), which include patent numbers and titles, technology classes, inventors' and assignees' names and addresses[13]. The address data were converted to the geographic divisions as of 2015 based on the municipal transition history (https://uub.jp/upd/).[14]

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 updated several times during our observation period. For consistency, we use 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).

We employ the name-based matching of the University and the Technical College graduates and patent inventors (or patent applicants until 1909)[15]. 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). In the end, we have 7,249 patents matched to 1,504 University graduates-inventors, and 5,666 patents matched to 1,675 Technical College graduates-inventors.

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.

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[13] The detailed process of digitizing Japanese historical patent records is described in Inoue et al. (2020) (in Japanese).
[14] 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.
[15] 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 are listed for the same individual in *Shimeiroku* and *Ichiran* making it relatively easy to identify name changes. To maximize the matching performance, we also take into account old and different forms of kanji. The sources to track name changes include *Imperial University Ichiran*, *Gakushikai Kaiin Shimeiroku*, High-school Registries (*High-school Ichiran*), Japan Doctors Index (*Dainihon Hakushiroku*) and other online sources.

4. Descriptive Statistics

4.1 Longitudinal trends of graduates' inventions

Patenting activities by domestic inventors in Japan experienced a significant growth from its launch in 1885. Figure 1 shows this trend. The number of patents by domestic inventors granted in 1900 (447 patents) is over four times more than those in 1885 (99 patents), and that number in 1920 (1,363 patents) is over three times more than in 1900. Despite such exponential increase of total domestic inventions, the share of patents by the University and the Technical College graduates also rapidly increased, especially after the mid-1900s. In 1900, the shares of patents by the Imperial University graduates and the Technical College graduates in total were 1.1% and 1.3%, respectively, but went up to 9.4% and 7.3%, respectively, in 1920. Hence, the growth in graduates' inventions was much faster than that of overall domestic inventions.

Figure 2 shows the increase in the number of inventors from Universities and Technical Colleges by graduation cohorts and their breakdown by schools. Until the second University was established in Kyoto, the Tokyo Imperial University was the only supplier of university-educated inventors. Even after a couple of new Universities were launched, the Tokyo Imperial University kept a dominant supplier of inventors, as in the 1916-20 graduate cohort 50.1% (217/433) of the University graduate-inventors came from the Tokyo Imperial University. Similarly, even though at the time of 1920 there were nine public Technical Colleges, the Tokyo Technical College supplied 42.0% (196/467) of the Technical College graduate-inventors in the 1916-20 cohort, followed by Osaka (21.7%) and Sendai (10.9%).

4.2 Who became inventors?

The likelihood of becoming an inventor could vary depending on educational background. Table 4 displays the likelihood of being inventors by S&E degrees, schools, graduation cohorts, and majors (divisions). Among our sample of graduates (until the 1920 cohort), 20.5% of University science graduates (271 out of 1,322), 18.9% of University engineering graduates (1,231 out of 6,524), and 12.6% of the Technical College graduates (1,675 out of 13,321) became patent inventors. Among the Universities, the Tohoku Imperial University has the highest likelihood of producing inventors (28.7%), but it only had the science department. For the Technical Colleges, more recently established Technical Colleges were less likely to produce inventors in general, except Yonezawa (12.6%) and Kiryu (17.3%).

Panel C of Table 4 reports the likelihood of graduates being inventors across the graduation cohorts. For the Universities, the likelihood increased from 15.4% in the cohorts before 1890 to 20.9% in the cohort 1891-1900, and was stable afterwards. For the Technical Colleges, the likelihood gradually decreases from 17.8% in the cohorts before 1890 to 10.8% in the cohort 1911-20, mostly because of the fact that more graduates in the late cohorts increasingly came from the colleges established later, which were less likely to produce inventors. As a matter of fact, if limited to the graduates from the Tokyo Technical College, the likelihood of being an inventor is fairly stable despite the fact that the number of total graduates exploded: 17.8% (28/157) in the cohorts before 1890 and 16.3% (410/2,516) in the cohorts 1911-20 became inventors.

Much more variation in the likelihood of becoming inventors obtains across divisions, as shown in Panel D of Table 4. Among the University graduates, the divisions most likely to produce inventors are chemistry in science (42.8%) and applied chemistry in engineering (40.6%), followed by electric engineering (24.2%), mechanical engineering (22.5%) and physics in science (22.5%). While these divisions in Technical Colleges also tend to produce relatively more inventors, it is notable that some specializations related to light industries, such as ceramics (17.2%), dyeing (18.7%), and weaving (11.2%) also have relatively higher likelihood of producing inventors.

4.3 Performance comparison between University graduates vs. Technical College graduates vs. other inventors

We now turn to comparing individual-level invention performance across University graduates, Technical College graduates, and other domestic inventors. In employing these comparisons we need to limit the sample to patents granted until 1920. This is because we have the graduate sample only until the 1920 cohort, those who graduated after the period and produced patents are categorized into 'other domestic inventors'. Limiting the patents to those granted until 1920 makes it clear that all those categorized in 'other domestic inventors' are neither University nor Technical College graduates. Table 5 summarizes the key statistics on various metrics. Conditional on being an inventor, University and Technical College graduates tend to produce more patents on average than other inventors: 2.6 patents among University graduates and 2.1 patents among Technical College graduates in their careers, relative to 1.6 patents among other inventors. Patent productivity is typically skewed, as shown by the fact that 73.6% of other inventors produced only one patent, whereas those fractions are 50.6% and 59.6% for University and Technical College graduates, respectively. The graduates were more productive than other inventors not only in the quantity of patents they produced but also in their quality: 2.8% of the University graduate-inventors and 1.3% of the Technical College graduate-inventors produced at least one patent listed in the patent catalog (*Teikoku Hatsumeika Meikan*), while that likelihood was 0.6% for other inventors.

Some other metrics reported in Table 6 highlight patenting behaviors across the inventor groups. In particular, University graduates are 1.6 percentage points more likely than other inventors and 1.0% more likely than the Technical College graduates to produce at least one co-inventing patent with another inventor, while those differences are not statistically significant. When they had more than one patent, University graduates' inventions tend to span across multiple fields more than others by 11.3 percentage points and Technical College graduates by 8.0 percentage points.

4.4 Technological classes and S&E divisions

Inventions in particular technological fields are clearly dependent on the supply of specialized talent in corresponding areas. Table 6 displays technological classes with high intensity of patenting by graduates in four major engineering divisions—applied chemistry, electric engineering, mechanical engineering, and metal and mining. It clearly shows that graduates tend to patent in fields where their specialization is closely related. The most frequently patented field by applied chemistry graduates is inorganic chemical compounds (12.5%), followed by mineral oil and liquid fuel (8.0%) and pigments, paints, adhesion (5.4%). Similarly, electric engineering graduates are likely to produce electricity-related inventions, such as power generation, electric power (14.3%), electricity transmission (7.9%), and electric substation (7.1%). The patenting fields of mechanical engineering are a little broader, ranging from spinning (4.3%) or weaving (5.3%) to combustion engine (4.8%) and power generation, electric power (4.8%). Finally, around 35.7% of inventions by metal and mining graduates are accounted for by metallurgy, alloy, and metal heat processes.

As already shown in Table 2 and 3, different universities and technical colleges covered different ranges of S&E fields, and even within each university and college the timings of opening divisions varied. Taken together with the fact highlighted in Table 6, this implies that the establishment of new schools and divisions associated with particular technological fields would lead to disproportionate growth of inventions.

4.5 Geography of inventions

In this subsection we consider the location of graduates' inventions. Figure 3 illustrates the relationships between patent intensity and industry statistics (industry output/number of plants/number of workers) by prefectures. We obtained these industry statistics from National Factory Repository (*Kojo Tsuran*) for three data points, 1909, 1914, and 1919. Each plot in Figure 3 represents the prefecture-by-year observations and the number of patents applied within five years starting from each data point (e.g., the period 1909-1913 for the year 1909), calculated for each prefecture. In Panel A, one percentage increase in industry output is associated with 0.84% increase in the University graduates' patents, 0.74% increase in the Technical College graduates' patents, and 0.76% increase in non-graduates' patents. The coefficient for University graduates is statistically significantly different from that for Technical College graduates (p=0.040) and for other inventors (p=0.045). There is no statistically significant difference between Technical College graduates and other inventors. Similar patterns are observed for the number of plants and workers, each of which is shown in Panel B and C. Taken together, this suggests that while patents produced by Technical College graduates and other inventors are similarly related to industrial activity, University graduates' patents tend to concentrate somewhat more in regions with more intensive industrial activity. By itself, this does not speak to whether more intense industrial activity tended to result in higher demand for university-educated inventors or whether the presence of university-educated inventors tended to boost industrial activity. Examining this relationship further is a task for future research.

We also examine how graduates' geographic origins are related to their likelihood of inventions in particular regions. In Panel A of Table 7, we estimate the likelihood of graduates patenting in regions proximate to their graduating schools. In column (1), conditional on the graduation cohorts and their birthplaces, those who graduated from Tokyo Imperial University or Tokyo Technical College have 25.1% higher chance of patenting in Tokyo relative to those from other Universities or Technical Colleges. Similarly, based on column (2), graduates from the University or the Technical Colleges in Osaka or Kyoto are 19.9% more likely to patent in those regions compared with other schools' graduates, and those from schools in the Kyushu region have 8.7% more likely to patent in the Kyushu region. In Panel B, we examine the associations between the location of graduates' inventions and their birthplaces, conditional on their graduation cohorts and schools. The results suggest that birthplaces are also significantly associated with the likelihood of inventions in those regions. Column (1) of Panel B shows that graduates born in Tokyo are

19.6% more likely to patent in Tokyo. From columns (2) and (3), the similar statistics for Osaka/Kyoto and the Kyushu region are respectively 18.9% and 8.6%.

4.6 Employers where graduates patented

In this subsection we describe the patterns of graduates' employment at the time of patent.[16] As described earlier, combining the alumni records (*Shimeiroku* for University graduates and each college's *Koto Kogyo Gakko Ichiran* for Technical College graduates) independent of patent publication records enables us to track employers where patenting occurred more accurately and broadly than solely relying on patent assignee information (which often did not include the employer during our sample). Figure 4 shows the longitudinal change in the shares of three sectors—industry, public administration, and university/research institutions—at the time graduates applied for patents. As shown in Panel A of Figure 4, Until 1905, 59.3% of patents were applied for by University graduates in industries while the remainder was equally allocated to public administration and university/research institutions. The fraction of university/research institutions increased over time while that of public administrations went down and that of industries remained stable, suggesting that among University graduates, academic scientists had increased their presence in inventions over time. In contrast, Panel B of Figure 4 shows that the fraction of Technical College graduates working for Universities or research institutions had been relatively smaller, ranging from 8.7% to 13.1%. Instead, the majority of patents were produced by those in industries and this fraction had dramatically increased over time. In the period of 1926-1930, four out of five patents by Technical College graduates were produced by industry scientists or engineers. This is consistent with the intentions of Technical Colleges to supply industrial engineers rather than technocrats.

Tables 8 and 9 summarize specific major employers of University and Technical College graduates at the time of patents. As mentioned, the Imperial Universities themselves were major employers for the University graduates-inventors at the time of patent. Table 9 shows that throughout the period, University of Tokyo had always been the top employer in terms of the number of patents its employees (faculty) produced. In earlier periods, many of the University graduates were absorbed by the public sector (Abe and Nakamura, 2010) and so were those who became inventors. Hence several public institutions—such as Ministry of Communications, Ministry of Railroads, and the Military—appear in Table 8 but their importance seems to wane over time.

[16] We assign the employer "at the time of patent" based on the patent application year, not the year the patent was granted.

Last but not least, several major companies such as *Shibaura Seisakujo* (electronic products, current Toshiba), Furukawa Mining (mining and chemical industry, current Furukawa), *Mitsubishi Zosenjo* (shipbuilding, current Mitsubishi Heavy Industry) were also the major employers of university graduates-inventors. Of special notice is the appearance, later in the sample, of companies like Hitachi Seisakusho, Ajinomoto and some others among the top employers—because these companies were actually *founded* by university graduates-inventors in our sample. Finally, there were also several public research institutions where university-educated scientists and engineers actively patented, including Tokyo Industrial Laboratory (*Tokyo Kogyo Shikenjo*), The Ministry of Communications Electrical Laboratory (*Teishinsho Denki Shikenjo*), Institute of Physical and Chemical Research (*RIKEN*).

In contrast, the list of major employers for Technical College graduates-inventors includes many more business companies, as shown in Table 9. Until 1910 and in 1911-20, the top employer of those inventors was *Shibaura Seisakujo* and it was taken over by *Hitachi Seisakujo* in 1921-30. Notably, Panel C shows that in the period 1921-30 four among the top five employers were companies producing electronic products. While some major companies in heavy industries that appear in Table 8 also appear in Table 9, there are also several firms in light industries—*Ohji Seishi* in paper industry, *Osaka Boseki*, *Toyo Boseki*, *Kanegafuchi Boseki* in cotton-spinning industry, and *Taiwan Seito* in sugar production.

5. Conclusion

In this study, we take the first step to understand the role of scientists and engineers graduated from Imperial Universities and Technical Colleges in domestic inventions during Japan's industrialization. We combine archival patent records with the graduates' education background and annual-based job and domicile information from their first graduation cohort to observe who among the graduates became inventors, when and where they invented, and how such patterns changed over time.

Despite the exponential growth of overall domestic patented inventions since the instance of the patent law, higher S&E graduates had substantially increased their presence in domestic inventions. While the major suppliers of college-graduated inventors were Tokyo Imperial University and Tokyo Technical College, around the half of the inventions by graduate-inventors in the 1910s were accounted for by those from later established universities and technical colleges. The likelihood of becoming inventors considerably varied across divisions, and the divisions with higher likelihood of producing inventors include chemistry in science departments, applied chemistry, electric engineering, and mechanical engineering in engineering departments. University and Technical College graduates tend to be more productive inventors relative to non-graduates in terms of the quantity of inventions, and University inventors are the most likely to produce high-quality inventions, measured by the likelihood of their patents listed in the catalog. When it comes to employers where they invented, University graduates were more likely to be working for universities or research institutions when patenting, while for Technical College graduates the employers were mostly private companies. Finally, regarding the geography of inventions, the location of graduates' inventions tended to be linked with the location of schools or their birth regions, and University graduates were slightly more likely to produce inventions in regions where economic activities were intense.

We believe there are plenty of opportunities for future research based on this study. Our database is unique in that it allows us to track University and Technical College S&E graduates from their *first* graduation cohort and their patent records from the *first* year of the patent system. A future study can take advantage of the co-evolutionary aspect of higher S&E education and industries/technologies at those initial stage, and elucidate how the matching of the graduates and the employers had evolved over time. The annual-based employer and domicile information enables researchers to examine in which career stages those graduates produced inventions, and how educational backgrounds, job experiences and organization tenures had differential and synergistic effects on inventions. Relatedly, graduates' mobility and prior career histories, in conjunction with their educational background, will be one of the research streams to which futures studies based on this database could contribute. Entrepreneurship by highly educated S&E human capital could be another research direction, given that our casual observations ensured that there were lots of prominent inventors who launched a company, and some of those companies still present. Finally, by further combining organization-level information, future studies could investigate how hiring capable scientists and engineers who have invention experiences has an impact on organization survival and performance.

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Figure 1: Historical Trends of Total Patents and Ratios of Patents by Graduates

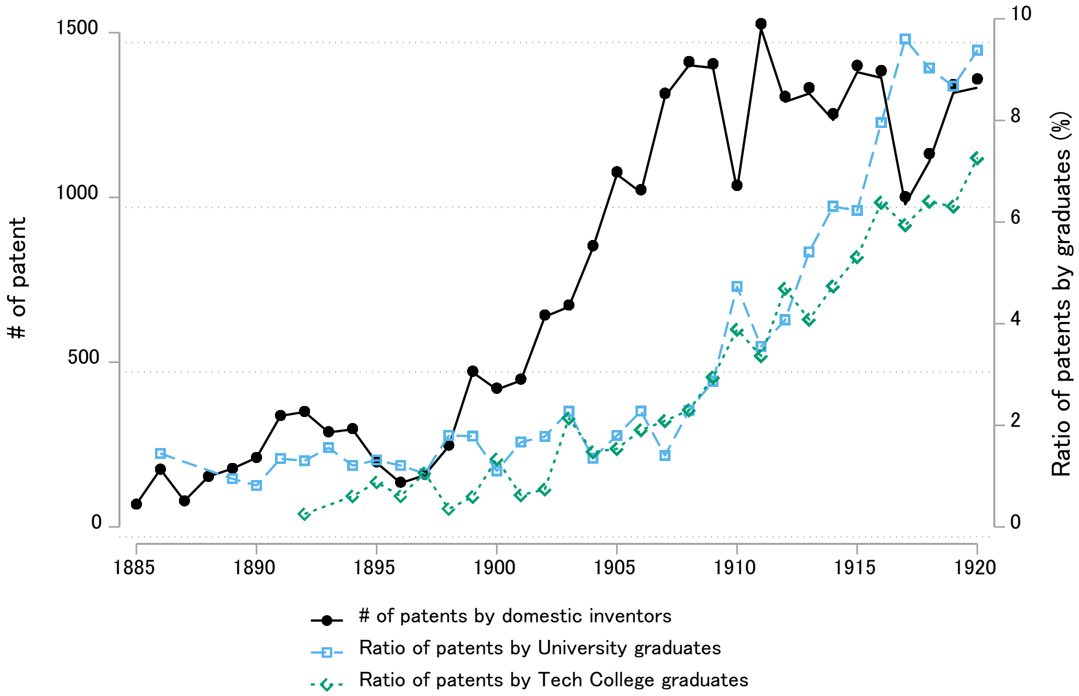


Figure 2: Number of inventors by graduation cohorts

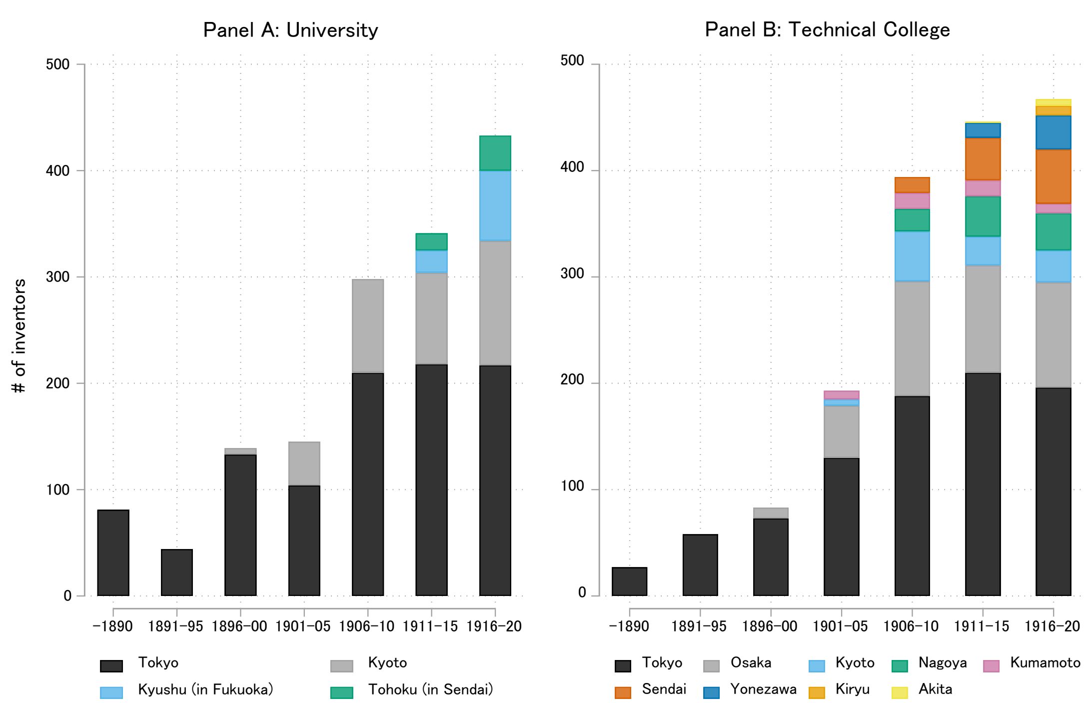
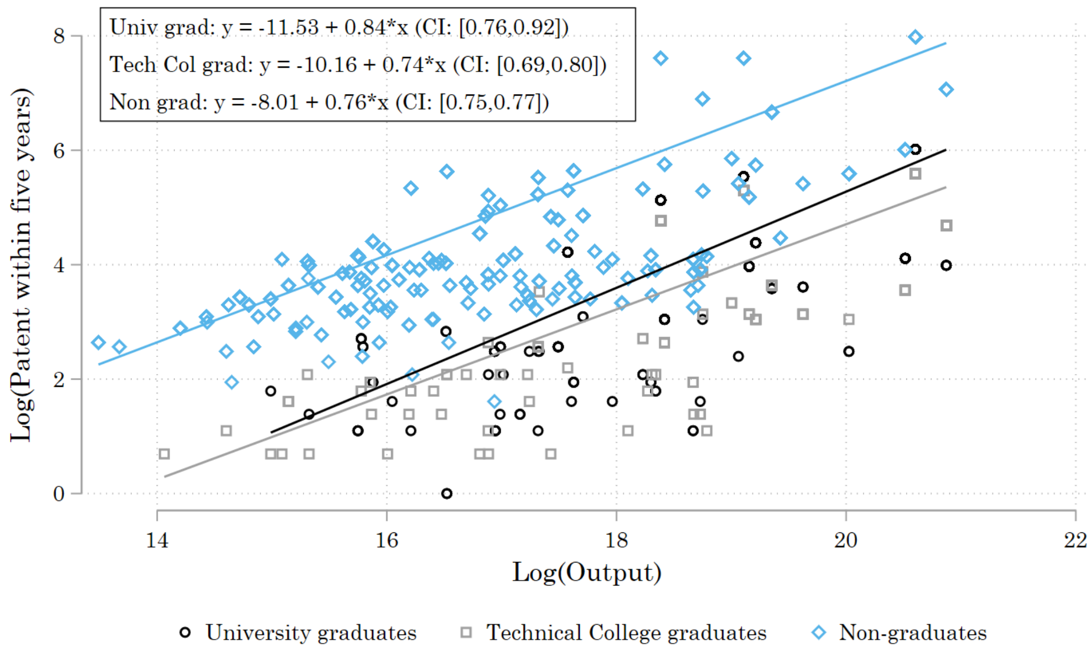
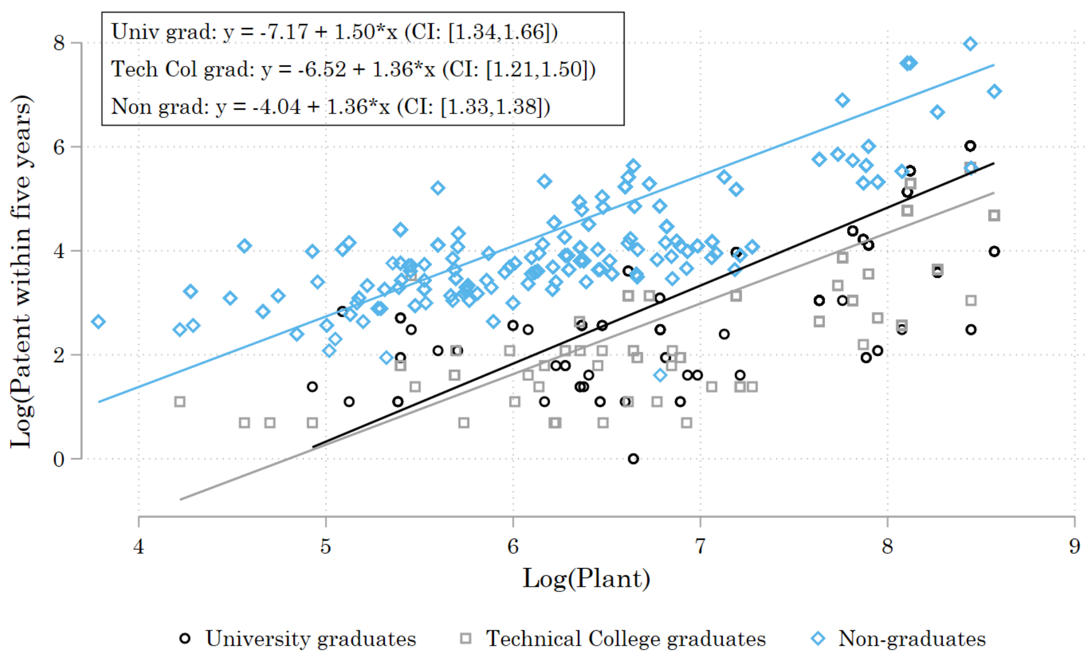


Figure 3: Industry measures by prefectures and inventions

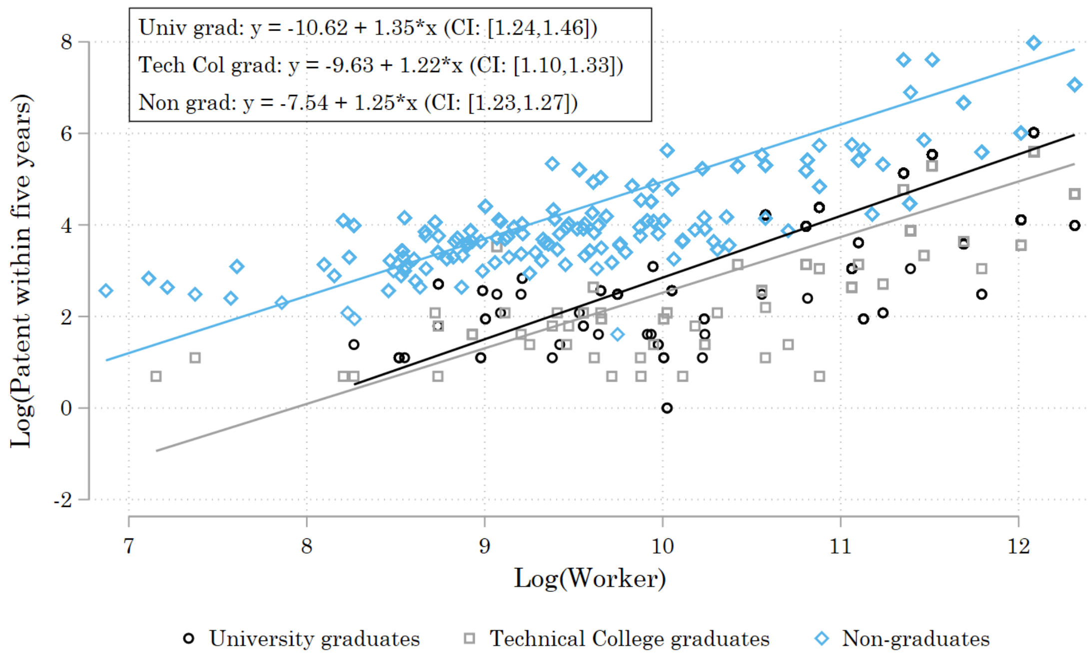
Panel A: Industry Output



Panel B: Number of Plants



Panel C: Number of Workers



Notes: The data for industry outputs (JPY), the number of plants, and the number of workers are derived from the National Factory Repository (*Kojo Tsuran*). The data periods are 1909, 1914, and 1919. The number of patents is based on patents applied within five years starting from each data point (i.e., patents applied in 1909-1913 for the year of 1909).

Figure 4: Patenting by industry/government/academic sectors

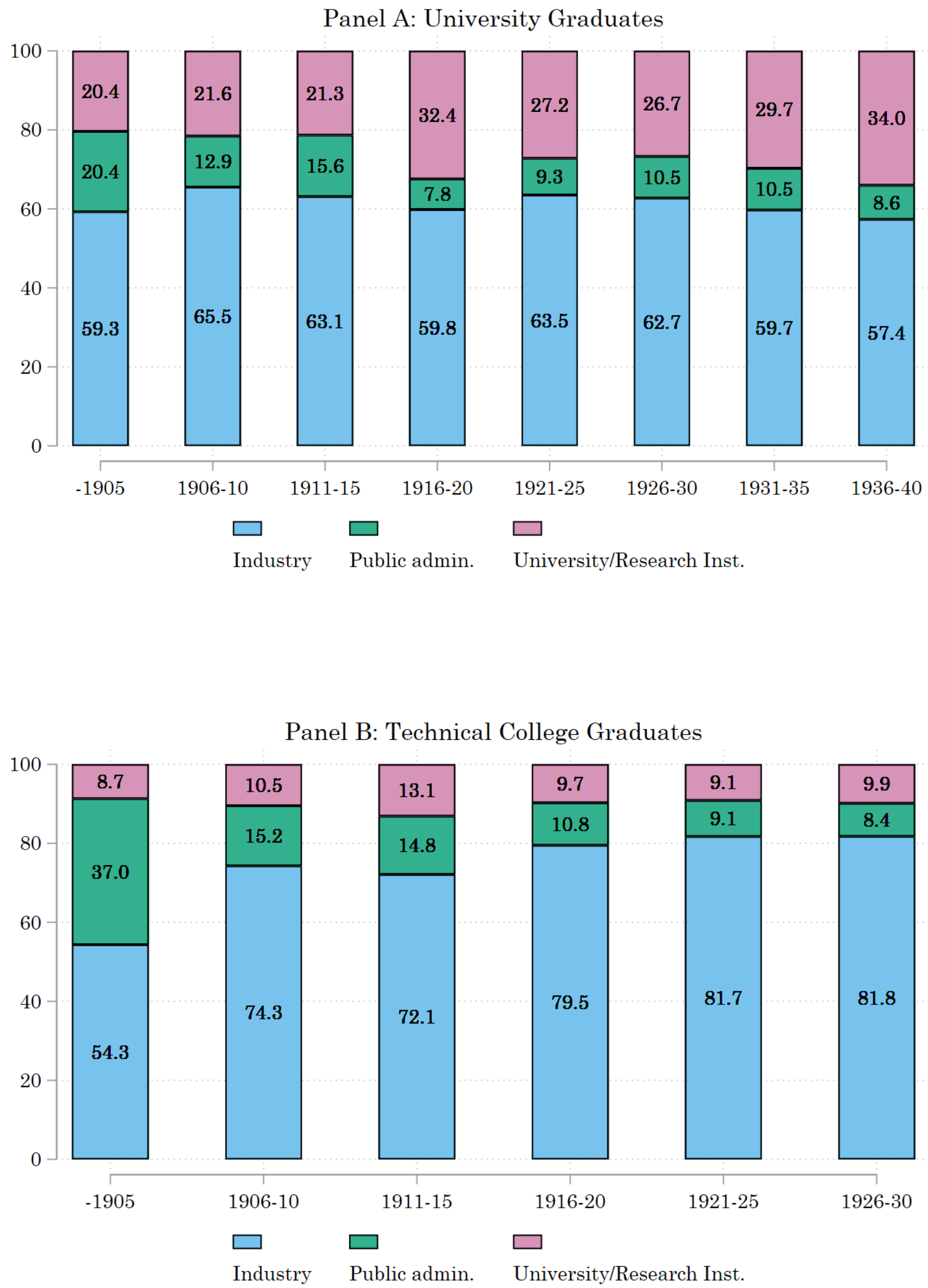


Table 1. University graduates by division until 1920 cohort

	Tokyo		Kyoto		Kyushu		Tohoku	
	First cohort	Pct. (N)	First cohort	Pct. (N)	First cohort	Pct. (N)	First cohort	Pct. (N)
Applied Chem.	1879	8.8 (474)	1902	10.5 (179)	1914	19.2 (95)	-	-
Architecture	1879	5.5 (298)	-	-	-	-	-	-
Civil Eng.	1878	17.4 (942)	1900	21 (357)	1914	15.8 (78)	-	-
Electric Eng.	1879	11.9 (643)	1901	21.4 (364)	1914	17.4 (86)	-	-
Marine Eng.	1898	3.5 (187)	-	-	-	-	-	-
Mechanical Eng.	1879	14.4 (777)	1900	21.6 (367)	1914	16.4 (81)	-	-
Metal and Mining	1879	12.1 (653)	1901	11.8 (200)	1914	31.2 (154)	-	-
Military Eng.	1890	1.9 (105)	-	-	-	-	-	-
Shipbuilding	1883	7.6 (412)	-	-	-	-	-	-
Chemistry (Sci.)	1877	3.4 (183)	1901	7.1 (120)	-	-	1914	37.4 (64)
Physics (Sci.)	1878	5.3 (284)	1902	2.6 (44)	-	-	1914	26.3 (45)
Other divisions	1879	8.2 (441)	1905	3.9 (67)	-	-	1914	36.3 (62)
Total		100 (5399)		100 (1698)		100 (494)		100 (171)

Notes: Missing cells are divisions that are not offered. Other divisions include Astronomy, Biology (Botany/Zoology), Geology Math, Mineralogy, Science divisions in science departments.

Table 2. Technical College graduates by division until 1920 cohort

	Tokyo		Osaka		Kyoto		Nagoya		Kumamoto	
	First cohort	Pct. (N)	First cohort	Pct. (N)	First cohort	Pct. (N)	First cohort	Pct. (N)	First cohort	Pct. (N)
Applied Chem.	1886	12.7 (700)	1900	13.2 (380)	-	-	1908	18.5 (226)	-	-
Architecture	1904	7.2 (398)	-	-	-	-	-	-	-	-
Brewery	-	-	1902	17 (491)	-	-	-	-	-	-
Ceramics	1889	5.9 (327)	1900	2.7 (79)	-	-	-	-	-	-
Civil Eng.	1895	1.6 (90)	-	-	-	-	1908	30.2 (369)	1901	35.9 (457)
Dyeing	1887	7.8 (430)	1900	0.9 (26)	1905	37.2 (362)	1908	10.3 (126)	-	-
Electric Eng.	1899	9.8 (542)	1910	7.8 (224)	-	-	-	-	-	-
Ind. Design	1900	4.6 (252)	-	-	1905	32.4 (315)	-	-	-	-
Manufacturing	1887	0.6 (33)	-	-	-	-	-	-	-	-
Marine Eng.	-	-	1903	9.8 (282)	-	-	-	-	-	-
Mechanical Eng.	1886	39.5 (2175)	1900	27.2 (786)	-	-	1909	24.1 (294)	1901	36.7 (467)
Metal and Mining	1895	1.1 (62)	1902	11.6 (334)	-	-	-	-	1909	27.5 (350)
Shipbuilding	-	-	1903	9.8 (284)	-	-	-	-	-	-
Weaving	1895	9.1 (499)	-	-	1906	30.3 (295)	1908	16.9 (206)	-	-
Total	1886	100 (5508)	1900	100 (2886)	1905	100 (972)	1908	100 (1221)	1901	100 (1274)

Table 2 (cont.). Technical College graduates by division until 1920 cohort

	Sendai		Yonezawa		Kiryu		Akita	
	First cohort	Pct. (N)	First cohort	Pct. (N)	First cohort	Pct. (N)	First cohort	Pct. (N)
Applied Chem.	-	-	1913	41.5 (152)	-	-	-	-
Architecture	-	-	-	-	-	-	-	-
Brewery	-	-	-	-	-	-	-	-
Ceramics	-	-	-	-	-	-	-	-
Civil Eng.	1910	25.3 (328)	-	-	-	-	-	-
Dyeing	-	-	1913	9 (33)	1919	34.6 (18)	-	-
Electric Eng.	1910	28.8 (374)	-	-	-	-	-	-
Ind. Design	-	-	-	-	-	-	-	-
Manufacturing	-	-	-	-	-	-	-	-
Marine Eng.	-	-	-	-	-	-	-	-
Mechanical Eng.	1910	25.8 (335)	1916	25.1 (92)	-	-	-	-
Metal and Mining	1910	20.1 (261)	-	-	-	-	1914	100 (283)
Shipbuilding	-	-	-	-	-	-	-	-
Weaving	-	-	1913	24.3 (89)	1919	65.4 (34)	-	-
Total	1910	100 (1298)	1913	100 (366)	1919	100 (52)	1914	100 (283)

Notes: Missing cells are divisions that are not offered.

Table 3. Observable Periods of Technical College Graduates' Job History

	School (graduation year of first cohort)							
	Tokyo (1886)	Osaka (1900)	Kyoto (1905)	Nagoya (1908)	Kumamoto (1901)	Sendai (1910)	Yonezawa (1913)	Kiryu (1919)
1891-1900	✓							
1901	✓	✓						
1902	✓	✓						
1903	✓	✓						
1904	✓	✓						
1905	✓	✓	✓					
1906	✓	✓	✓					
1907	✓	✓	✓					
1908	✓	✓	✓		✓			
1909	✓	✓	✓		✓			
1910	✓	✓	✓	✓	✓			
1911	✓	✓	✓		✓	✓		
1912	✓	✓	✓		✓	✓		
1913	✓	✓	✓	✓	✓	✓		
1914	✓	✓	✓	✓	✓	✓	✓	
1915	✓	✓	✓	✓	✓	✓	✓	
1916	✓	✓		✓			✓	
1917	✓	✓	✓	✓	✓	✓	✓	
1918	✓	✓	✓	✓	✓	✓	✓	
1919	✓	✓	✓	✓	✓	✓	✓	✓
1920	✓	✓	✓	✓	✓	✓	✓	
1921	✓	✓		✓	✓	✓	✓	✓
1922	✓	✓		✓		✓	✓	✓
1923		✓	✓	✓	✓	✓	✓	✓
1924	✓	✓	✓	✓	✓	✓	✓	✓
1925	✓	✓		✓	✓	✓	✓	✓
1926	✓	✓		✓		✓	✓	✓
1927	✓		✓	✓		✓	✓	✓
1928	✓		✓	✓		✓	✓	✓
1929	✓		✓	✓		✓	✓	✓
1930	✓		✓	✓		✓	✓	✓

Table 4: Likelihood of graduates becoming inventors

University	Likelihood (%)	Technical College	Likelihood (%)
	Panel A: By degree		
Engineering	18.9	Engineering	12.6
Science	20.5		
Total	19.1		
	Panel B: By school		
Tokyo	18.7	Tokyo	17.3
Kyoto	20.1	Osaka	13.1
Kyushu	17.6	Kyoto	11.5
Tohoku	28.7	Nagoya	8.0
		Kumamoto	3.7
		Sendai	8.4
		Yonezawa	12.6
		Kiryu	17.3
		Akita	2.5
	Panel C: By graduation cohort		
-1890	15.4	-1890	17.8
1891-00	20.9	1891-00	16.7
1901-10	18.5	1901-10	15.5
1911-20	19.5	1911-20	10.8
	Panel D: By S&E division		
Applied Chem.	40.6	Applied Chem.	22.7
Architecture	8.1	Architecture	2.9
Civil Eng.	6.8	Brewery	9.2
Electric Eng.	24.2	Ceramics	17.2
Marine Eng.	21.3	Civil Eng.	2.4
Mechanical Eng.	22.5	Dyeing	18.7
Metal & Mining	13.8	Electric Eng.	17
Military Eng.	16.2	Ind. Design	5.0
Shipbuilding	12.3	Manufacturing	20.7
Chemistry (Sci.)	42.8	Marine Eng.	10.4
Physics (Sci.)	22.5	Mechanical Eng.	16.0
Others	6.3	Metal & Mining	4.7
		Shipbuilding	6.7
		Weaving	11.2

Table 5. Comparison of inventor groups: the University graduates, the Tech College graduates, Others (Patents granted until 1920)

Variables	University graduates	Tech. College graduates	Others	Univ. grad - Others difference	Tech College. grad - Others difference	Univ. grad. - Tech College grad difference
N patents	2.630	2.054	1.631	0.999***	0.423***	0.576***
	(2.990)	(2.090)	(2.238)	(0.125)	(0.087)	(0.151)
1(≥ 2 patents)	0.494	0.404	0.264	0.230***	0.140***	0.090***
	(0.500)	(0.491)	(0.441)	(0.021)	(0.020)	(0.029)
1(at least one patent listed in patent catalog)	0.028	0.013	0.006	0.021***	0.007	0.014*
	(0.164)	(0.115)	(0.078)	(0.007)	(0.005)	(0.008)
1(at least one co-inventing patent)	0.336	0.310	0.319	0.016	-0.010	0.026
	(0.473)	(0.463)	(0.466)	(0.020)	(0.019)	(0.027)
N inventors	581	597	18,522			
* Among inventors of ≥ 2 patents						
1(patenting in ≥2 tech. fields)	0.748	0.668	0.635	0.113***	0.033	0.080**
	(0.435)	(0.472)	(0.481)	(0.027)	(0.031)	(0.040)
N inventors	282	235	4,826			

Notes: 'Others' include only domestic inventors. Patenting period refers to periods between the first patenting year and the last patenting year based on applications. Standard deviations (first three columns) and robust standard errors (last three columns) are in parentheses.

Table 6. Major technological classes by graduates from patent-intensive engineering divisions

Panel A: Applied chemistry

Technological class	Pct. (N)
Inorganic chemical compounds	12.5 (347)
Mineral oil, liquid fuel	8 (224)
Pigments, paints, adhesion	5.4 (151)
Organic chemical compounds	5.2 (145)
Rubber, thermoplastic	5 (139)
Oil and fats, detergent	4.5 (126)
Metallurgy, alloy, metal heat process	3.8 (105)
Fertilizer	3.7 (103)
General chemistry	3.1 (85)
Cement, artificial stone, asphalt	3.1 (85)
Other classes	25.5 (723)
Total	100 (2,798)

Panel B: Electric Engineering

Technological class	Pct. (N)
Power generation, electric power	14.3 (332)
Electricity transmission	7.9 (183)
Electric substation	7.1 (164)
General electric component	6.2 (144)
High frequency telecommunication	5.8 (135)
Measuring electric power and magnetic charge	3.6 (83)
Inorganic chemical compounds	3.5 (80)
Railroad	3.1 (71)
Telecommunication	2.9 (66)
Battery	2.4 (56)
Other classes	24.5 (605)
Total	100 (2,354)

Panel C: Mechanical Engineering

Technological class	Pct. (N)
Weaving	5.3 (204)
Combustine engine	4.8 (187)
Power generation, electric power	4.8 (186)
Spinning, processing of thread	4.3 (168)
Transportation	3.6 (141)
Pumps	3.5 (135)
General electric component	3.3 (128)
Metal processing	2.9 (111)
Artificial fiber	2.8 (107)
Crushing, mixing, separation	2.5 (97)
Other classes	42.7 (1,722)
Total	100 (3,942)

Panel D: Metal and Mining

Technological class	Pct. (N)
Metallurgy, alloy, metal heat process	35.7 (330)
Metal processing	8.3 (77)
Exploration, mining, beneficiation	6.5 (60)
Inorganic chemical compounds	5.8 (54)
Solid fuels, gas fuels	4.2 (39)
Casting	3 (28)
Cement, artificial stone, asphalt	3 (28)
Heating	2.7 (25)
Pigments, paints, adhesion	2.7 (25)
Foods, nutritional supplements	1.8 (17)
Other classes	12.6 (92)
Total	100 (641)

Notes: Technological classes are based on the Patent Classification Index ("Tokyo Bunrui-betsu Somokuroku").

Table 7. Geographic localization of inventions

VARIABLES	(1) 1(Patent in Tokyo)	(2) 1(Patent in Osaka or Kyoto)	(3) 1(Patent in Kyushu region)
Panel A: Geographic localization based on University/Technical College			
University or Technical College in Tokyo	0.251***		
	(0.046)		
University or Technical College in Osaka or Kyoto		0.199***	
		(0.036)	
University or Technical College in the Kyushu region			0.087***
			(0.018)
Constant	0.191	0.206**	0.034
	(0.116)	(0.084)	(0.048)
Observations	13,479	13,479	13,479
R-squared	0.175	0.165	0.068
Cohort FE	Yes	Yes	Yes
Birthplace FE	Yes	Yes	Yes
Panel B: Geographic localization based on birthplaces			
Birthplace in Tokyo	0.196***		
	(0.019)		
Birthplace in Osaka or Kyoto		0.189***	
		(0.037)	
Birthplace in the Kyushu region			0.086***
			(0.024)
Constant	0.352***	0.077	0.019
	(0.115)	(0.058)	(0.018)
Observations	13,479	13,479	13,479
R-squared	0.159	0.156	0.049
Cohort FE	Yes	Yes	Yes
University/Technical College FE	Yes	Yes	Yes

Notes: The sample is based on patents produced either by the University or the Technical College graduates until 1940. The Kyushu region includes Fukuoka, Kagoshima, Kumamoto, Miyazaki, Nagasaki, Ohita, Okinawa, Saga prefectures. In Panel A, the schools in Tokyo are Tokyo Imperial University and Tokyo Technical College. The schools in Osaka or Kyoto are Kyoto Imperial University, Osaka Technical College, and Kyoto Technical College. The schools in the Kyushu region are Kyushu Imperial University and Kumamoto Technical College. Robust standard errors in parentheses are clustered at schools in Panel A and at prefectures in Panel B. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8. Employers When The University graduates Patented

Panel A: -1910

Employer	Rank	Pct. (N)
Univ. of Tokyo	1	6 (16)
Shibaura Seisakujo	2	4.5 (12)
Furukawa Mining	3	3.8 (10)
Military	4	3 (8)
Ministry of Communications	5	2.6 (7)
Ishikawajima Zosenjo	6	1.9 (5)
Kyoto University	7	1.9 (5)
Ministry of Railroads	8	1.5 (4)
Osaka tech. college	8	1.5 (4)
Takada Shokai	8	1.5 (4)
Teishinsho Denki Shikenjo	8	1.5 (4)
Fujinagata Zosen	12	1.1 (3)
Kisha Seizo	12	1.1 (3)
Nihon Tetsudo	12	1.1 (3)
Tokyo Dento	12	1.1 (3)
Toyo Mokuzai Bofu	12	1.1 (3)
Tsukishima Kikai Seisakujo	12	1.1 (3)

Panel B: 1911-20

Employer	Rank	Pct. (N)
Univ. of Tokyo	1	4.8 (37)
Kyoto University	2	4.2 (32)
Shibaura Seisakujo	3	3.1 (24)
Ministry of Communications	4	2.9 (22)
Furukawa Mining	5	2 (15)
Ministry of Railroads	5	2 (15)
Mitsui Mining	7	1.8 (14)
Tohoku University	7	1.8 (14)
Kawasaki Zosenjo	9	1.6 (12)
Teishinsho Denki Shikenjo	9	1.6 (12)
Mitsubishi Zosenjo	11	1.3 (10)
Takada Shokai	11	1.3 (10)
Hitachi Mine	13	1.2 (9)
Military	13	1.2 (9)
Kyoto tech. college	15	1 (8)
Minami Manshu Tetsudo	15	1 (8)
Shimadu Seisakujo	15	1 (8)
Tokyo Kogyo Shikenjo	15	1 (8)

Panel C: 1921-30

Employer	Rank	Pct. (N)
Univ. of Tokyo	1	5.4 (94)
Mitsubishi Zosenjo	2	3.8 (67)
Kyoto University	3	3.7 (64)
Mitsui Mining	4	3.1 (54)
Tohoku University	5	2.6 (46)
Military	6	2.3 (40)
Hitachi Seisakujo	7	2.1 (37)
Ministry of Railroads	8	1.9 (33)
Rikagaku Kenkyujo	8	1.9 (33)
Tokyo Kogyo Shikenjo	10	1.8 (31)
Tokyo Denki	11	1.3 (23)
Teishinsho Denki Shikenjo	12	1.3 (22)
Shibaura Seisakujo	13	1.2 (21)
Furukawa Denko	14	1.1 (19)
Suzuki Shoten/Ajinomoto	15	1 (17)
Aoyagi Kenkyujo	16	0.9 (16)
Denki Kagaku Kogyo/Denka	16	0.9 (16)
Mitsubishi Mining	16	0.9 (16)

Panel D: 1931-40

Employer	Rank	Pct. (N)
Univ. of Tokyo	1	8 (117)
Kyoto University	2	3.8 (56)
Tohoku University	3	3.1 (46)
Mitsubishi Zosenjo	4	2.8 (41)
Mitsui Mining	5	2.7 (40)
Tokyo Kogyo Shikenjo	6	2.3 (34)
Military	7	2.2 (32)
Nihon Sekiyu	7	2.2 (32)
Rikagaku Kenkyujo	9	1.9 (28)
Furukawa Denko	10	1.4 (21)
Hitachi Seisakujo	10	1.4 (21)
Ministry of Railroads	10	1.4 (21)
Waseda University	13	1.3 (19)
Sumitomo Densen Seizojo	14	1.2 (17)
Teishinsho Denki Shikenjo	15	1.1 (16)
Asahi Glass	16	0.9 (13)
Dainihon Jinzo Hiryo	17	0.8 (11)
Ministry of Interior	17	0.8 (11)

Table 9. Employers When Technical College Graduates Patented

Panel A: -1910

Employer	Rank	Pct. (N)
Shibaura Seisakujo	1	4.7 (11)
Tokyo tech. college	1	4.7 (11)
Military	3	3 (7)
Mitsubishi Zosenjo	4	2.2 (5)
Ministry of Railroads	5	1.7 (4)
Osaka tech. college	5	1.7 (4)
Mie Cement	7	1.3 (3)
Ohji Seishi	7	1.3 (3)
Sumitomo Chuko	7	1.3 (3)
Furukawa Mining	10	0.9 (2)
Kobukuro Kosakujo	10	0.9 (2)
Kyoto Menneru	10	0.9 (2)
Nihon Sekiyu	10	0.9 (2)
Oka Tekkojo	10	0.9 (2)
Osaka Boseki	10	0.9 (2)
Shinagawa Shirorenga Cement	10	0.9 (2)

Panel B: 1911-20

Employer	Rank	Pct. (N)
Shibaura Seisakujo	1	6.2 (43)
Tokyo tech. college	2	2.4 (17)
Takada Shokai	3	1.7 (12)
Mitsubishi Zosenjo	4	1.6 (11)
Hitachi Seisakujo	5	1.3 (9)
Waseda University	6	1.2 (8)
Ikegai Tekkojo	7	1 (7)
Furukawa Denko	8	0.9 (6)
Kure Kaigun Kosho	8	0.9 (6)
Ministry of Railroads	8	0.9 (6)
Tokyo Gas	8	0.9 (6)
Furukawa Mining	12	0.7 (5)
Ishikawajima Zosenjo	12	0.7 (5)
Minami Manshu Tetsudo	12	0.7 (5)
Nihon Denki	12	0.7 (5)
Niigata Tekkojo	12	0.7 (5)

Panel C: 1921-30

Employer	Rank	Pct. (N)
Hitachi Seisakujo	1	6.9 (116)
Shibaura Seisakujo	2	5.3 (89)
Mitsubishi Zosenjo	3	1.8 (31)
Mitsubishi Denki	4	1.4 (23)
Tokyo Denki	5	1.3 (22)
Military	6	1.1 (19)
Meidensha	6	1.1 (18)
Toyo Boseki	8	0.9 (15)
Teishinsho Denki Shikenjo	9	0.8 (14)
Ishikawajima Zosenjo	10	0.8 (13)
Dainihon Jinzo Hiryo	11	0.6 (10)
Kanegafuchi Boseki	11	0.6 (10)
Taiwan Seito	11	0.6 (10)
Tohoku University	11	0.6 (10)
Tokyo Kogyo Shikenjo	11	0.6 (10)
Furukawa Denko	16	0.5 (9)
Ikegai Tekkojo	16	0.5 (9)
Rikagaku Kenkyujo	16	0.5 (9)