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Teaching to the Tests: An Economic Analysis of Traditional and Modern Education in Late Imperial and Republican China

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Abstract

A traditional education system, based on the Confucian classics, was a pillar of imperial China's social structure for centuries, preparing elites for a series of highly competitive exams conferring gentry status and civil service positions. Reformers in late imperial China called for the modernization of educational institutions, seeing in Western education the skills necessary to develop China's economy. In the late 19th century, the traditional education system was joined by a "modern", Western track, which offered teaching in science, math, social science, law, and engineering. In this paper, early 20th century employee records from the Tianjin-Pukou Railroad are analyzed to identify differences in labor market outcomes associated with study in the traditional and modern educational systems. The employee records reveal that modern and traditional education were both associated with wage premiums, but that these were significantly larger for individuals trained at high levels in the modern system, especially those trained in engineering. Individuals trained in the traditional system worked disproportionately in the clerical department of the railroad, while those with modern education were more often in managerial and technical roles. Qualitative and quantitative evidence suggests that these results are not driven by sorting into educational institutions according to ability. These findings indicate that beyond years of schooling, the *content* of schooling can play an important role in the process of economic development.

Keywords: Educational Content, Educational Institutions, Industrial Development, Republican China
JEL Codes: I25, J24, N15, N35, O14

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1 Introduction

A traditional education system, based on the Confucian classics, was a pillar of imperial China's social structure, government, and economy for centuries. Study in traditional schools prepared students to take a series of highly competitive exams that conferred gentry status and civil service positions upon those who passed. Elman (2000, p. xvii) writes, "In China since medieval times, imperial dynasties, gentry-literati elites, and classical studies were tightly intertwined in the operation of the civil service examinations. All three were perpetuated during the late empire (1368–1911), and they stabilized for five hundred years because of their interdependence."

Military defeats at the hands of Western countries (in Opium Wars ending in 1842 and 1860) as well as Japan (in the Sino-Japanese War of 1894–1895) indicated to many Chinese the need for institutional change. Among the changes proposed were reforms to the structure and content of the imperial exams, and thus to the content of the education system. There were passionate statements made on both sides of the debate over educational reform. Those in favor saw clear links among international competitiveness, economic modernization, and educational reform. Elman (2006, p. 201) writes of a Qing official who felt that "the military successes of Meiji Japan were a model for China and that emulating the Japanese would require expanded education in the sciences and industry." In 1898, the *Guangxu* Emperor wrote, "Our scholars are now without solid and practical education; our artisans are without scientific instructors; when compared with other countries we soon see how weak we are" (Headland, n.d., p. 116). In contrast, rather than view Meiji Japan as a paragon, conservatives argued that "For five thousand years the spirit of the sages has continued in China ... [we] absolutely must not do as the Japanese, who had dispensed with their own learning in favor of Western learning" (Weston, 2002, p. 108).[1]

[1]Of course, such passion may have been due to a desire to maintain rents accruing to conservatives as much

Beginning in the second half of the 19th century, a modern (Western) educational track gradually developed in imperial China. Military arsenal schools, first established in the 1860s by the Qing government as part of a movement toward "self strengthening," translated Western scientific texts into Chinese, and provided training necessary for the adoption of Western military technologies (Elman, 2006). A small modern educational hierarchy, including high schools and colleges, developed as well, especially in the treaty ports controlled by Western powers. These modern schools were often staffed by missionaries, and taught foreign languages and Western math and science. Chinese students were also able to access Western knowledge through study abroad.

While the cultural, social, and political consequences of the China's Confucian education system and imperial civil service exams have received a great deal of attention (for example, Chang, 1955; Ho, 1962; Miyazaki, 1981; Chaffee, 1995; Elman, 2000), very little direct evidence exists on the consequences of the establishment of modern, Western schools; micro-level evidence is particularly scarce.[2] Were reformers in the late Qing correct that the human capital produced by training in modern subjects—especially Western science and engineering—was crucial to the development of modern industry in China? Or was the rigorous academic training of the traditional education system useful and general enough to make traditionally-educated individuals productive even in modern, industrial firms?

In this work, I undertake a quantitative comparison of modern and traditional educational institutions in late imperial and republican China using micro-level data on individuals' educational backgrounds and their labor market outcomes. I use a sample of

as it was due to a love of classical Chinese learning. Hon (2002, p. 96) writes that, "conservatives had many reasons to object to reform, especially political reform. Some were antiquarians; others were by nature skeptical of change. But a large number were 'corrupt bureaucrats' (*suli*) who had a vested interest in preserving the political status quo." Cantoni and Yuchtman (2013) discuss the political economy of educational reform in Qing China in more detail.

[2]Bai (2014) shows that after the traditional civil service exams were abolished, prefectures sending more students to Japan for the study of modern subjects also experienced an increase in the establishment of modern firms.

employee records from the Tianjin-Pukou (JinPu) Railroad that were compiled in 1929 to examine the associations between employees' educational backgrounds and their labor market outcomes—both their wages and occupations at the railroad.[3] If the human capital produced in modern, Western schools was more productive in modern, industrial firms, one would expect to see large wage premiums paid to individuals trained in the modern education system, relative to individuals trained in the traditional system, *ceteris paribus*.[4] If traditional and modern education provided very different skills, one would also expect individuals trained in the two systems to sort into different occupations.[5]

At the broadest level, I find that traditional and modern education are in fact associated with *very similar* wage premiums, relative to unskilled workers at the railroad. This suggests the traditional system did produce skills that were useful to modern, industrial firms. However, when educational background is disaggregated, one sees enormous premiums paid to modern university and, especially, engineering training, dwarfing the pay to individuals with even high levels of traditional education. University-trained engineers earned around 100 percent more, on average, than individuals trained at a high level in the traditional system; employees with modern university training in other fields (such as

[3]The data are imperfect: the sample is a convenience sample, and some employees' wages are not observed, but rather inferred from pay scales. Still, the data are extremely valuable: datasets containing information on individuals' education and wages in the early 1900s are difficult to find even in the United States (see Goldin and Katz, 2000). Not only is it unusual to observe employee records that include information on education and salaries at this time, but it is even more remarkable to observe employees trained in *both* modern and traditional educational systems, allowing one to compare salaries and occupations depending on whether an employee studied traditional or modern subjects.

[4]Throughout this work, I assume that differences in salaries represent differences in employees' marginal product, and the existence of generally well-functioning, competitive labor markets. This is only a rough approximation in any labor market, though Rawski (1989) suggests that Chinese labor markets were quite well-functioning by 1929, the year the employee records I analyze were compiled. Still, this assumption requires further attention; I discuss differing degrees of friction in the labor markets facing individuals in the traditional and modern education systems below (see Section 4).

[5]Roy (1951) presents a canonical model of sorting into occupations according to differences in productivity. In the empirical work below, I focus on sorting across occupations within a firm. Of course, individuals would be expected to select across firms (and industries) as well as across occupations within a firm; I discuss selection across firms and industries, and how these affect the conclusions that can be drawn from a single firm's employee records, in detail below (see Section 4).

business, law, and economics) earned around 40 percent more than individuals trained at a high level in the traditional system. One also sees striking differences in occupations associated with educational background. Employees trained in the modern education system were significantly more often in managerial and railroad planning positions; traditionally-educated workers were disproportionately employed in clerical positions. These results suggest that modern education, indeed, produced differentially valuable human capital to modern, industrial firms. This human capital generated a higher wage, and was put to use in different occupations at the JinPu Railroad.

These findings from the JinPu Railroad contribute to a growing body of research aimed at understanding the economic development experiences of late imperial and republican China, both the sluggish modernization in the late imperial period, and the economic growth in the republican era. This literature builds on a large body of research on the Needham Puzzle and the "Great Divergence", which is focused on the questions of why Europe was able to economically and technologically surpass China, and why Europe, but not China, experienced an indigenous industrial revolution.[6]

Historians and economists have discussed the economic consequences associated with the traditional education system in the context of the "Great Divergence" literature: Huff (2003) argues that traditional Chinese education was too closely linked to the structure of the imperial government and the official ideology; thus, there was no insulated space for researchers to conduct potentially disruptive scientific research, as there was in Europe. Lin (1995) argues that Chinese elites were incentivized to invest in human capital that would produce examination success, rather than scientific discovery. Their work highlights the role of traditional education in China's historical development, but lacks systematic empirical evidence with which to substantiate this link. The JinPu employee records allow for

[6]See, among others, Mokyr (1990), Pomeranz (2000), Morris (2010), Rosenthal and Wong (2011), Hoffman (2012), Ashraf and Galor (2013), and Brandt et al. (2014).

a novel *individual*-level analysis of the economic consequences of traditional and modern Chinese education. By examining the microeconomic, labor market outcomes associated with each educational system, one can better understand the human capital generated in each system, and the role that modern educational institutions played in China's development. In addition to providing new evidence of productivity (i.e., wage) differences associated with study in different educational institutions, this article complements work on the Great Divergence by studying the role of educational institutions in China's failure to *adopt* industrial technologies in the Qing, as well as China's more successful modernization during the republican period.[7]

Recent work has linked the introduction of Western ideas and institutions to more successful episodes of economic development in late imperial and republican China. Ma (2004, 2006, 2008) focuses on the role of political and legal institutions in promoting growth in the first half of the twentieth century, with the Shanghai region experiencing especially rapid growth as a result of the better, foreign, institutions there. Jia (2014) shows that the treaty ports controlled by Western powers experienced more rapid growth than other cities with similar geographic characteristics. Bai and Kung (forthcoming) present evidence that Chinese counties with more Protestant missionaries were more urbanized (and thus plausibly more developed) than other counties in the early 20th century.[8] Complementing their work, in this article I point to the importance of Western education, especially training in engineering, in China's ability to adopt Western industrial technologies (Elman, 2006 and Chang, 1993 make arguments along these lines as well).

More generally, the analysis here builds on work by Barro (1991), Mankiw et al. (1992), Galor and Weil (2000), Glaeser et al. (2004), Galor and Moav (2006), and Goldin and Katz

[7]Sng and Moriguchi (2014) argue that Meiji Japan's far more successful modernization in the 19th century, vis á vis China, can be attributed to greater state capacity in the former.

[8]Jia (2014) and Chen et al. (2014) present evidence that Western influence had persistent consequences into the late 20th century.

(2010) emphasizing the role of human capital investments in the process of industrialization, technological change, and the rise of modern economic growth. My findings provide suggestive evidence that educational content and the choice of educational institutions—the types of human capital invested in, in addition to quantities of human capital—matter for productivity, and thus can play an important role in the process of economic development.[9]

The paper will proceed as follows: in Section 2, I discuss the differences in content and structure between the traditional and modern educational systems. In Section 3, I analyze the JinPu Railroad employee records, providing a brief description of the Railroad and its employee records, then examining salary and occupational differences across employees with differing educational backgrounds. In Section 4, I discuss several important concerns regarding the interpretation of my findings. Finally, in Section 5, I provide a summary and conclude.

2 Comparing Educational Tracks

Traditional and modern educational institutions in 19th century China were structured differently, with different objectives, suggesting that they produced very different forms of human capital. In this subsection, I provide an overview of the two systems.

[9] Along similar lines, Cantoni and Yuchtman (2014) argue that the establishment of universities in medieval Europe supported economic activity through the legal training provided (see also Cantoni and Yuchtman, 2013). Squicciarini and Voigländer (2014) argue that upper tail, scientific knowledge was crucial to the adoption of industrial revolution technologies in France; and, Jones (2014) makes a related argument, that the "depth" of training is crucial to economic growth. Hanushek and Kimko (2000) make the complementary argument that human capital *quality* must be considered alongside quantity in studying the relationship between education and growth.

2.1 The Traditional Chinese Education System

The traditional Chinese education system provided training in the Confucian classics as preparation for a series of highly competitive exams, beginning at the local level, then rising to the national-level exams in Beijing that were used to select individuals for service in the imperial bureaucracy.[10]

The number of traditionally-educated students is very difficult to estimate precisely (traditional schooling was almost entirely decentralized, so there is no single source of enrollment data). Chang (1955) estimates that there were nearly 1,000,000 degree-holding members of the Chinese gentry in the late 19th century; as the exams were highly competitive (even at the lowest levels), there were surely many more than 1,000,000 individuals enrolled in schools and academies that constituted the traditional system.[11]

Students preparing for the exams began their studies as young children, first learning basic Chinese characters, and as they progressed, memorizing the thousands of characters from which the Confucian classics were composed.[12] After mastering the basic characters, students would study Tang dynasty (618–907 A.D.) poetry and begin working through the Four Books and the Five Classics (the classical texts on which they would be examined). Many years of diligent study were required to master and memorize these books; for example, Zhang Jian, a scholar in the second half of the 19th century, could recite the Four Books from memory at age 12, after nine years of study; many examination candidates studied well into their 20s and 30s (and some even longer). Students would devote yet

[10] It is important to note that the traditional education system served political, cultural and social functions beyond its usefulness in selecting bureaucrats and its provision of human capital (see Chaffee, 1995; Elman, 2000).

[11] The lower levels of the traditional education system, schools organized at the clan-, or village-level, provided millions of children with some level of literacy. Rawski (1979) argues that perhaps 30 percent of Chinese had some ability to read; these individuals likely studied for some time in a traditional school, but with aims less ambitious than achieving gentry status. Baten et al. (2010) show that 19th century Chinese were relatively numerate as well.

[12] The description of training for the exams comes from Elman (2000, p. 275) which is based on the education of scholar Zhang Jian in the second half of the 19th century.

more time to practicing their composition skills—most importantly, the "eight-legged essays" they were forced to produce on their examinations—and reading commentaries and histories that would be useful for their exams.

Perhaps the most striking aspect of traditional training was its narrow focus: mastery of the Confucian classics and the ability to write the eight-legged essays were almost exclusively the skills that determined a candidate's success on the exams in the late Qing.[13] Importantly (and understandably), students responded to the incentives offered by the examination system and often did not seek broad educations that went beyond the material needed to succeed in the exams.

The narrow focus of the exams was recognized as a problem by reformers in the second half of the 19th century. Among other proposed reforms, attempts were made to introduce new, Western subjects—particularly the sciences—into the civil service exams, and thus into the traditional curriculum.[14] However, changes in the content of the imperial exams in the 19th century were unsuccessful in encouraging serious study of modern science among those preparing for the imperial exams. Exam prompts regarding Western science were philosophical, rather than applied, such as the following: "Much of European science originates from China; we need to stress what became a lost learning as the basis for wealth and power" (Elman, 2006, p. 145). Furthermore, essays on Western science were judged according to their stylistic and literary merit, rather than scientific aptitude. Elman writes, "The civil examinations were the last bastion of traditional Chinese science, where the 'Chinese origins' approach to Western learning remained obligatory."

Calls for comprehensive educational and examination reform briefly bore fruit, in the

[13]The metropolitan examination, which qualified individuals for imperial civil service positions, contained a section on the Four Books and poetry, a section on the Five Classics, and a section on Policy. However, the policy questions were "typically overlooked" by graders (Elman, 2000, p. 523).

[14]These efforts were badly needed: Elman (2006) writes, "By 1750, textbooks made the application of mechanical principles accessible to anyone literate in English or French, and artisans and engineers applied them. None were translated into Chinese, because the Jesuits [who controlled the transfer of Western science to China in the 18th century] never made the jump to the mathematicization of practical mechanics."

100-days reform of 1898.[15] But, as the name suggests, reform did not last, as conservatives quickly re-asserted themselves, maintaining the traditional curriculum and exams until 1905. Until then, to receive useful training in Western science one needed to exit the traditional system and enter a modern school that did not train students for the imperial exams.

2.2 Modern, Western Education in Late Imperial and Republican China

During the second half of the 19th century, the Qing engaged in a limited set of educational reforms, part of the "Self Strengthening" movement. Military arsenal schools were first established in the 1860s by the Qing government. These schools produced translations of Western books and scientific journals, and provided training in science and engineering that was aimed at producing militarily useful skills and knowledge, though this knowledge was also useful in nonmilitary fields.

A modern educational hierarchy, including high schools and universities, taught Western subjects as well, including modern mathematics and sciences, foreign languages, and engineering. These schools were often staffed by missionaries, and were often located in the treaty ports established after the Opium Wars. The important role played by Westerners in the expansion of modern education in China can be seen in the actions taken by the British company, John Swire and Sons, in the early 20th century.[16] In 1909, the company granted £40,000 toward the establishment of the University of Hong Kong.[17] Of the first three academic chairs to be established, one was to be in "'Applied Science,' for the education of Railway, Mining and Electrical Engineers, Surveyors, etc. (of whom [China]

[15] Karl and Zarrow (2002) discuss the educational and political reforms of 1898, as well as their legacy.

[16] Swire and Sons was the predecessor to the extant firm, Swire Group. In the early 20th century, its China business included trade, shipping, refineries, dock management, and finance.

[17] Swire and Sons Archive, JSSI 4/3 Box 1171.

stands greatly in need for the development of her resources)."[18] The firm makes explicit the applied aims of the training to be provided; in a letter, a company official wrote:

> The project is neither purely Altruistic nor purely Utilitarian. I claim for it an eminently practical basis benefitting China and ourselves equally. The benefits to China have already been summarized, and it is needless to dwell on the immense alleviation of human suffering which will result from a steady output of Chinese medical men working among their own people and of Chinese engineers who can assist in averting the constantly recurring famines and loss of life due to inundations of rivers and lack of irrigation, or the wealth and prosperity which would accrue to the teeming poverty-stricken population by the opening up of railways and mines, and improvements in agriculture and forestry.[19]

In the last quarter of the 19th century, Chinese students were also able to access Western knowledge through study abroad. Japan, which had already reformed its educational institutions, and incorporated the teaching of Western science, was the most important destination for Chinese students. The United States also played an important role in training Chinese in Western subjects like medicine, engineering, and law.

While conservatives in the imperial government were able to prevent large-scale reforms in the late 19th century, they faced continual pressure, and their control over educational institutions was short-lived. The traditional examination system was finally abolished in 1905, just a short time before the last Qing emperor abdicated the throne, in 1912.[20] As reformers had believed, eliminating the incentives for studying the Confucian classics (provided by the traditional civil service exams) led the modern education system to grow

[18] JSSI 4/3 Box 1171.
[19] JSSI 4/3 Box 1171.
[20] Wright (1968) discusses revolutionary developments in China in the first decade of the 20th century.

rapidly, from around 4,000,000 students in the 1910s to over 12,000,000 in the 1930s (Yan, 2007, Table 8).

2.3 Summary: Comparing Traditional and Modern Education

Traditional and modern educational institutions in late 19th century China differed greatly in the training they provided: in the traditional system, one would master the Confucian classics and perfect one's writing skills; in the modern system, one would take courses on Western subjects, whether languages, mathematics, engineering, or law. *Ex ante*, it seems likely that individuals trained in the modern system would be very productive and earn high wages in modern firms, especially if they possessed training in fields like engineering. What is less clear is whether the traditional education system produced human capital that was valuable to modern, industrial firms.

On the one hand, one might think that studying the classics and writing essays would not produce the technical skills necessary to work in or manage a modern firm. On the other hand, the traditional Chinese education system provided precisely the sort of classical liberal arts training that was offered in the English universities in the 18th and 19th centuries, during the Industrial Revolution.[21] The traditional education system forced students to memorize huge amounts of material, to think about abstract concepts, and to write persuasively—all intellectual skills that could serve them well in a variety of positions, perhaps especially in administrative and managerial roles. The extraordinary levels of persistence and discipline demanded by the traditional system surely imparted valuable non-cognitive skills (Heckman et al., 2006). Thus, while traditionally-educated individuals might play different roles from individuals trained in the modern system, it is not obvious whether traditionally-educated individuals would be less productive than those educated

[21] See Coleman (1973) for a discussion of debates in Britain regarding classical and practical education during and after the Industrial Revolution.

in the modern system, even within an industrial firm like the JinPu Railroad.

3 Examining Labor Market Outcomes Using Tianjin-Pukou Railroad Employee Data

3.1 Background: the JinPu Railroad

The JinPu Railroad was a joint German-British venture, initiated in 1898, to link Northern China to the rich Shanghai-Nanjing region.[22] Initially, the railroad relied almost exclusively on non-Chinese for skilled labor. The track was finally completed in 1912, though by this time the railroad was under the control of the recently-established Republic of China (yet still financed by foreign capital). The railroad was successful, despite the fact that it was surrounded by political uncertainty: Köll (2009) writes, "[T]he JinPu line soon became a serious competitor [against the Grand Canal] for goods transportation into Hebei, Shandong, and Anhui provinces and strengthened the commercial ties between Shanghai and eastern Shandong."[23] The railroad was fortunate not to be the site of many conflicts between labor and management, as were other Chinese railroads in the 1920s.

In 1928, the Nationalist Government's Ministry of Railroads took control of the JinPu Railroad, and centralized aspects of hiring and pay, specifically for the skilled workers who are the focus of this study.[24] Shortly after taking control, the Ministry collected information on skilled workers, including salary and educational background, providing a rare source of early 20th century data on these two variables for a sample of Chinese workers.

[22] This section draws on Köll (2009). Morgan (2001) provides a detailed description of railroad personnel policies in republican China.

[23] The political environment was constantly changing: the Germans in Shandong province were replaced by Japanese after World War I, then the Japanese replaced several years later by Chinese, and until 1928, China was fought over by warlords. Still, the railroad continued to function successfully.

[24] The Nationalist Government, based in Nanjing, took control of China in 1928 as well.

3.2 Description of the Dataset

The sample I analyze consists of a cross-section of 829 Railroad employees; the records are not a random sample, but are a broad sample of the JinPu Railroad's workers (a page from the employee records is provided in Appendix Figure A.1).[25] Very low skill, manual laborers, who comprised a sizable fraction of railroad workers, are not included, however. The workers in the sample were employed in a variety of occupations, from clerks to police officers, to managers, to engineers. For each employee, the Railroad's records contain information on age, province of origin, occupation title, department, monthly salary (or pay grade), tenure with the Railroad, level and type of schooling completed, and prior work experience.

Two-thirds of the employees in the dataset received a salary and one-third had an assigned pay grade. Pay grades are converted into salaries using the mapping provided in the 1932 Railway Yearbook (*Tiedao Nianjian*), the earliest yearbook I could find with salaries matched to pay grades. Concerns about the conversion of pay grades into salaries distorting inferences are discussed in Section 4.

Summary statistics for the sample of employees are shown in Table 1. Yearly salaries are high by the standards of republican China: Rawski (1989, p. 310) cites miners in China in 1927 earning around $100 per year, while the JinPu workers in the sample earn nearly $1,000 per year.[26] Workers in the sample, on average, had worked for the JinPu Railroad for nearly six years when the records were compiled, and many of them had worked in the railroad industry prior to their employment with the JinPu Railroad (nearly 60 percent). The distribution of yearly salaries can be seen in Figure 1, smoothed using the Epanechnikov kernel density estimator. The graph has the familiar log-normal shape, and in the

[25] The sample was originally collected by Professor Elisabeth Köll.

[26] All monetary quantities are expressed in Chinese dollars. The exchange rate between the Chinese dollar and the U.S. dollar in 1929 ranged from 2.2 Chinese dollars per U.S. dollar to 2.7 Chinese dollars per U.S. dollar (numbers taken from the Global Financial Data database).

Table 1: Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
yearly salary	806	960.61	746.40	180	6600
age (years)	757	36.91	9.26	16	74
tenure (years)	802	5.99	7.08	0	24
prior jobs	829	2.50	1.99	0	11
railroad experience	829	0.59	0.49	0	1
industry experience	829	0.21	0.41	0	1
government experience	829	0.31	0.46	0	1
teaching experience	829	0.12	0.32	0	1
military experience	829	0.20	0.40	0	1
banking experience	829	0.03	0.16	0	1

Note: Salary denominated in Chinese dollars, which exchanged for American dollars at approximately 2.5 Chinese dollars per American dollar. "Prior jobs" is a count of jobs worked prior to the current position with the JinPu Railroad that are listed in the employee's record; the "experience" variables are dummy variables equal to 1 if an employee had experience in the relevant category listed in his record. The number of observations varies due to some missing values.

empirical analysis, log salaries will be examined.

In Table 2, one can see summary statistics for a set of educational category dummy variables constructed from the employee records. These variables equal 1 if an individual was trained in the relevant education system, or, in the case of *no education*, if the education field was blank in the employee records.[27] These broad categories do not use all of the available information on educational background (I exploit this information further, by disaggregating these categories, below), but they are an informative first cut of the data.

[27] In the empirical work that follows, I exclude individuals without information on educational background, because this group includes both individuals with no formal education and individuals whose educational background was missing. Results are very similar when these individuals are included as a separate category.

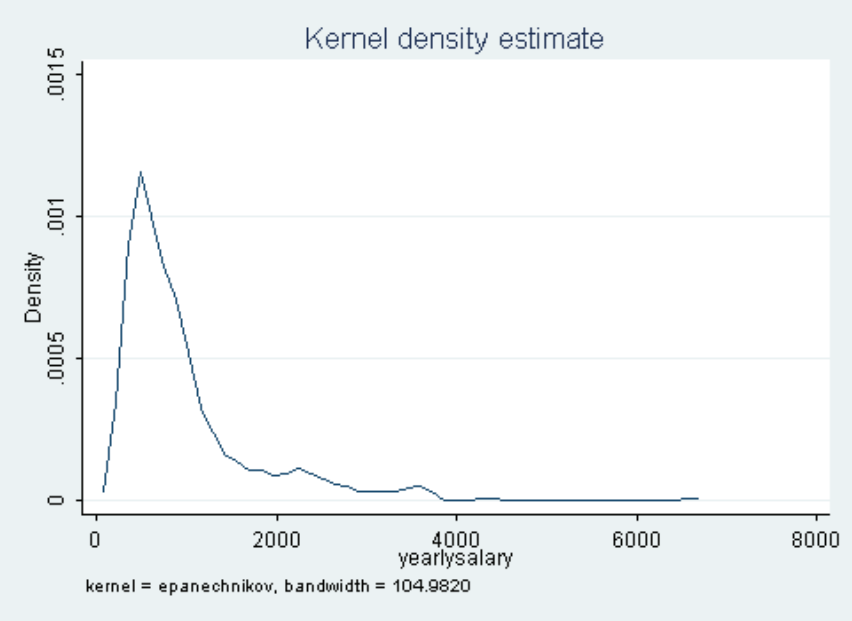

Figure 1: Distribution of yearly salaries. Salaries come from 806 workers with information on salary or grade, with grades converted into salaries using the conversion from the 1932 Railway Yearbook.

Table 2: Summary Statistics by Broad Education Category

Category	Obs.	Mean	Number	Ave. Salary	Ave. Age	Ave. Tenure	Prior RR Exper.	Num. Prior Jobs
modern	829	0.585	485	1020.5	34.4	5.4	0.64	2.6
traditional	829	0.057	47	1174.2	43.6	8.3	0.57	2.9
military	829	0.082	68	969.6	36.7	3.8	0.41	3.3
apprentice	829	0.018	15	1042.4	46.3	9.9	0.80	3.0
police	829	0.082	68	600.7	39.1	6.6	0.74	3.0
no education	829	0.176	146	837.5	44.0	7.8	0.44	1.3

Note: "Obs." refers to the number of individuals in the sample; "Mean" is the average value of each educational category dummy variable in the entire sample; and, "Number" refers to the number of individuals in the relevant educational category in the sample. Salary is denominated in Chinese dollars; age and tenure are in years; prior railroad experience is a dummy equal to 1 if an individual had experience with a railroad prior to his current position with the JinPu Railroad; the number of prior jobs is simply a count of prior jobs listed in the employee's record with the JinPu Railroad. Averages within an educational category are for the individuals with a 1 for the relevant educational category dummy variable, and non-missing information for the particular variable.

Although the majority of individuals in the sample come from the modern system (59 percent, or 485 individuals), traditionally-educated workers are a non-trivial minority (5.7 percent, or 47 individuals), and one can see that, unconditionally, they are paid very well.[28] One can also see substantial differences in average age, tenure, and prior work experience associated with different educational backgrounds. Controlling for these characteristics will be important to the empirical analysis below. Of course, concerns about *unobserved* worker characteristics that are correlated with educational background and also with labor market outcomes will be a major challenge to the empirical analysis, and are discussed in more detail below (see Section 4).

3.3 Earnings Differences

To preview the analysis, Figure 2 presents box plots showing (raw) salary ranges by educational category for: (i) coarse educational categories—traditional education versus modern; (ii) narrow categories at the highest level of education—university training in the modern system versus higher-level traditional; and, (iii) narrow categories within the highest level of modern education—engineering training versus non-engineering university training versus higher-level traditional. One can see that modern education is associated with somewhat lower salaries than traditional education overall; university education is associated with slightly higher salaries than high levels of traditional education; and, engineering training at university associated with higher salaries than non-engineering university training, which in turn is associated with slightly higher salaries than high levels of traditional education.[29] These basic patterns are explored in more depth below.

[28] Note that some traditional schools introduced some teaching of modern subjects in the second half of the nineteenth century. Misclassification of individuals' educational backgrounds will bias results toward finding no difference across systems.

[29] The absence of outliers in salaries once logs are taken is reassuring given the relatively small cell sizes for narrower educational categories.

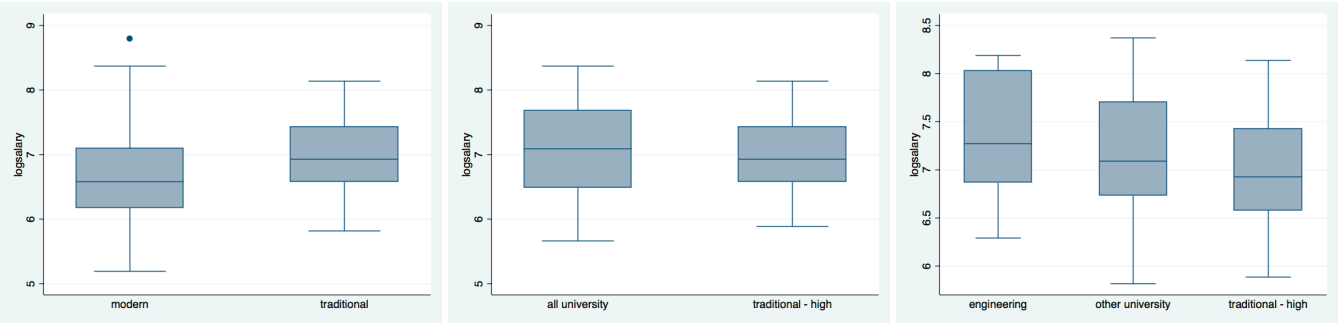

Figure 2: Comparisons of yearly salaries across educational categories. Salaries come from 806 workers with information on salary or grade, with grades converted into salaries using the conversion from the 1932 Railway Yearbook.

3.3.1 The Empirical Model

To associate differences in educational backgrounds with differences in salaries, I estimate the following model:

$$log(Salary)_i = \sum_c \beta_c Educ_{ci} + \gamma Z_i + \epsilon_i \quad (1)$$

The outcome variable is the log of the yearly salary of employee i. The explanatory variables of interest are a set of educational background dummy variables, $Educ_{ci}$ (with education categories indexed by c). To begin, the categories c will be the "broad" educational categories examined in Table 2: modern, traditional, military, apprenticeship, and police training (narrower categories are considered below). The model will also include a vector of individual-specific controls (Z_i), such as province of origin, age, tenure with the railroad, etc. (so γ is a vector), and an idiosyncratic error term. This specification is analogous to a Mincer (1974) earnings model used to estimate the returns to schooling, but in this case used to examine differences in earnings associated with *categories* of schooling c, rather than differences in earnings associated with *years* of schooling.[30]

I would like to interpret differences in the estimates of β_c as evidence of log salary differences *caused* by differences in employees' educational backgrounds, but of course, educational attainment in my sample is not randomly assigned. One might be particularly concerned about individuals with differing (unobserved) ability levels selecting systematically into particular educational categories. This important concern is discussed in detail below (see Section 4).

[30]Similar models have been estimated to examine the economic returns to students' choices of majors in contemporary settings (see Altonji et al., 2012 for a review of this literature).

3.3.2 Earnings Differences Across Broad Education Categories

I begin by estimating equation (1) using dummy variables for broad educational categories: *modern*, *traditional*, *military*, *apprenticeship*, and *police*. The *police* category—that is, education in a police academy—is the omitted group; employees in the *police* category received less training than those educated in the modern system, the traditional system, a military academy, or those who apprenticed at a railroad.

Table 3: Salary Differences Across Broad Education Categories

	Outcome variable: log(salary)				*MATCHING*
	(1)	(2)	(3)	(4)	(5)
modern	0.379***	0.410***	0.427***	0.586***	0.027
	[0.059]	[0.056]	[0.056]	[0.105]	[0.128]
traditional	0.600***	0.351**	0.414***	0.401***	
	[0.099]	[0.090]	[0.086]	[0.124]	
military	0.386***	0.314***	0.302***	0.353**	
	[0.088]	[0.082]	[0.079]	[0.175]	
apprentice	0.561***	0.270**	0.361***	0.403***	
	[0.118]	[0.113]	[0.126]	[0.138]	
police	omitted	omitted	omitted	omitted	
p-value: modern=traditional	0.016	0.475	0.853	0.088	0.834
obs.	674	665	660	222	518
r-squared	0.04	0.40	0.47	0.34	
controls	none	quadratic age, province dummies	quadratic age, cubic tenure, province dummies, prior railroad exper, num. prior jobs	quadratic age, province dummies	quadratic age, province dummies
employees included	all	all	all	age $\geq$ 40	traditional or modern school

Note: Robust standard errors in brackets. Regressions have log salary as an outcome, a set of dummy variables for broad education categories, and a set of controls. Columns 1-4 use OLS; column 5 uses nearest-neighbor matching on the sample of individuals educated in the traditional or modern system. * p<0.1, ** p<0.05, *** p<0.01

The results from estimating several specifications are presented in Table 3. In column (1), equation (1) is estimated without any controls—this simply produces results corresponding to what was seen in Table 2: it is interesting that in the raw correlations (without controls) traditional education is actually associated with significantly *higher* salaries than modern education.[31]

Of course, traditionally-educated individuals differ in many ways compared to the others. Thus, in columns (2) and (3) control variables are added to try to account for these differences. In column (2), quadratic controls for employee age and a set of dummy variables for province of origin are included, and their inclusion sharply reduces the estimated coefficient on *traditional*. The coefficient on *traditional* is now smaller than the coefficient on *modern*, though the two are statistically indistinguishable, and both are significantly greater than zero (indicating a skill premium for both modern and traditional education of around 40 percent, relative to the police academies).

In column (3), along with the controls included in column (2), a 3rd-order polynomial in tenure with the JinPu Railroad, the number of jobs worked prior to the current one, and prior experience with a railroad (using a dummy variable) are all added to the model (though one should keep in mind the caveat that prior work experience may be an endogenous outcome of individuals' educational backgrounds).[32] Adding these additional controls does not meaningfully change the results: the coefficients on *traditional* and *modern* are significantly different from zero, around 0.4 in magnitude, and statistically indistinguishable from each other. The results in Table 3, columns (1) through (3) are somewhat surprising: not only is traditional education associated with a large salary premium (rel-

[31] All calculations of significance are based on heteroskedasticity-robust standard error estimates. For the sake of brevity, the discussion of results will focus on the comparison between modern and traditional education. The results in Table 3 indicate that military education and apprenticeships were also valuable sources of human capital, but their analysis is left for future work.

[32] All reported results are robust to other specification choices as well, for example higher-order polynomial terms in age or tenure. Results available upon request.

ative to the relatively less skilled policemen), but it is also approximately as large as that received by individuals trained in the modern system.

I next subject these results to a pair of robustness tests. First, one might be concerned that selection into systems of education changed across cohorts as the traditional education system was reformed and eventually replaced. In particular, as discussed below (see Section 4) it is very likely that among the oldest cohorts in our sample, the very best students selected into the traditional system—it was far more prestigious, and remunerative, than the modern system prior to the 1900s (see Elman, 2006 and Chang, 1955). But among younger cohorts (among individuals who reached their teens after the civil service exams were abolished), selection might have flipped, favoring the modern system.

To examine whether shifts in selection affect the analysis, I estimate the specification from Table 3, column (2), but only for individuals at least 40 years old in the sample.[33] The results are shown in Table 3, column (4). Though the coefficients on the dummy variables *traditional* and *modern* are both larger than they were in column (2), the results are quite similar to those estimated using the unrestricted sample, suggesting that selection of better types into the traditional system among the older cohorts, and perhaps worse types among the younger cohorts does not greatly affect the results above. Interestingly, one can see a *widening* of the gap between employees educated in the traditional and modern systems (compare column 2 to column 4) despite the better selection into traditional education among the older cohorts. One possible explanation for this is that although there was "worse" selection into the modern system among older employees, they are paid relatively more due to the scarcity of their particular human capital among their own cohorts.

The second robustness check is to control for employee characteristics less paramet-

[33]The specification in Table 3, column (2) has the virtue of not including controls that may be endogenous outcomes of an individual's education. None of the results presented are sensitive to including the possibly endogenous controls that were included in Table 3, column (3). In addition, none of the results are sensitive to the inclusion of a full set of occupational department fixed effects (results available from the author upon request).

rically than was done above. To this end, I limit the sample to individuals trained in traditional or modern educational institutions, and estimate the average treatment effect of having a modern education using a nearest-neighbor matching estimator. I match observations on their province of origin and age. In Table 3, column (5), one can see that the matching estimate, too, shows a very small, statistically insignificant difference in log salaries between those educated in the traditional and in the modern system.

The results found using broad educational categories suggest that the difference between traditional and modern human capital is not as simple as Chinese reformers might have led one to believe: traditional education was associated with a salary very similar to that received by individuals trained in the modern system. But, the categories used above were crude: within the modern educational hierarchy, there may be a big difference between studying at a primary school and studying at the university level. At a given level of schooling, the human capital acquired studying different subjects may be very different. Thus, I disaggregate the broad schooling categories: first, I examine differences in salaries associated with narrower categories based on the level of schooling completed; then, I examine narrow categories based on the content studied.

3.3.3 Earnings Differences Across Narrow Education Categories: Levels of Education

The educational attainment of JinPu employees educated in the modern educational hierarchy can be divided into three levels: primary/middle school (192 individuals); secondary school (34 individuals); and, college/university (144 individuals). These are mutually exclusive sub-categories within the broad *modern* education category; they are not exhaustive, as they do not include individuals who attended missionary or vocational schools, the level of which typically cannot be identified in the employee records. Thus, in this analysis, I will focus on the subset of individuals who attended modern schools that were not missionary

or vocational schools (i.e., individuals who studied within the "modern hierarchy").

The individuals who studied in the traditional system are less easy to classify according to the level of their schooling. The employee records of only three individuals include notes indicating the passage of high level imperial exams, but more records indicate the amount of traditional education completed. I use this information to split the broad *traditional* education category into two parts: I create a "low-level traditional" category that includes employees whose records note that their level of education was "low" or that only "some" education in a traditional school was completed (13 individuals). The other individuals are classified as "high-level traditional" (34 individuals). This split is a mutually exclusive, exhaustive classification of the employees trained in the traditional system.[34]

Using this disaggregation of the modern educational hierarchy and the traditional education system ($c \in \{$*primary/middle, secondary, university/college, traditional low, traditional high*$\}$), I next estimate equation (1) on the sub-sample of employees educated within the modern hierarchy or the traditional system. In Table 4, column 1, one can see estimated coefficients (relative to modern primary/middle school education, the omitted category) on the disaggregated education level dummies, from a model including quadratic controls for employee age and province of origin fixed effects. One can see that salaries for employees with college or university education in the modern system are around 40 percent larger than salaries of employees educated at high levels in the traditional system or those of employees educated at the secondary level within the modern hierarchy. A high level of traditional education is associated with a significant salary premium (around 20%) relative to individuals educated in modern primary and middle schools, approximately the same as the premium associated with modern secondary education.

[34]Note that misclassification of individuals across levels of education will bias results toward finding no difference across categories. Note also that the absence of information on an individual's years of schooling makes it impossible to calculate the return to a year of schooling under the two different educational systems.

Table 4: Salary Differences Across Levels of Traditional and Modern Schooling

	Outcome variable: log(salary)			*MATCHING*
	(1)	(2)	(3)	(4)
modern university/college	0.519***	0.439***	0.820***	0.348**
	[0.068]	[0.065]	[0.147]	[0.162]
modern secondary	0.167*	0.124	0.287	
	[0.089]	[0.082]	[0.188]	
high traditional	0.182**	0.201**	0.239*	
	[0.090]	[0.083]	[0.140]	
low traditional	0.027	0.006	0.031	
	[0.233]	[0.231]	[0.287]	
modern primary/middle	omitted	omitted	omitted	
p-value: university=high traditional	≤ 0.001	0.012	≤ 0.001	0.032
obs.	405	403	122	174
r-squared	0.49	0.57	0.45	
controls	quadratic age, province dummies	quadratic age, cubic tenure, province dummies, prior railroad exper, num. prior jobs	quadratic age, province dummies	quadratic age, province dummies
employees in traditional hierarchy and modern hierarchy included	all	all	age ≥ 40	university or high-level traditional

Note: Robust standard errors in brackets. Regressions have log salary as an outcome, a set of dummy variables for narrow education categories, and a set of controls. Columns 1-3 use OLS; column 4 uses nearest-neighbor matching on the sample of individuals educated at a high level in the traditional system or at the university level in the modern system. * p<0.1, ** p<0.05, *** p<0.01

In Table 4, column 2, I add to the specification in column 1 controls for tenure with the JinPu Railroad and prior experience, and the results are qualitatively similar: modern tertiary education is associated with a significantly higher salary compared to high-level traditional education and to lower levels of the modern hierarchy. High-level traditional education is associated with a significantly higher salary than modern primary/middle school education, and a modestly (statistically insignificantly) higher salary than modern secondary schooling.

In column 3, the model from Table 4, column 1, is estimated on the sub-sample of individuals aged 40 or greater who were educated in the modern hierarchy or in the traditional system. Again, results are qualitatively unchanged, although (analogous to what was seen in Table 3) the estimated salary premium paid to individuals with modern tertiary education is much larger than when examining the whole sample. As discussed above, this suggests that scarcity of modern human capital among the oldest cohorts plays an important role in determining their salaries.

Finally, in Table 4, column 4, I present the estimated treatment effect of modern university/college education relative to high-level traditional education using a nearest-neighbor matching estimator (examining only employees trained at the tertiary level in the modern system and employees trained at a high level in the traditional system). One can see that the highest level of modern education is again associated with a significantly greater salary than high levels of traditional education.

The results in Table 4 suggest that critiques of traditional schooling must be qualified—education at high levels in the traditional system was associated with significantly greater salaries than those earned by employees with low levels of education within the modern hierarchy, and similar salaries to those earned by individuals educated at the secondary level in the modern system. But, they also provide strong support for the arguments of

the republican-era educational reformers: training at the tertiary level in the modern educational hierarchy was associated with an enormous salary premium, even relative to high levels of traditional schooling, suggesting that the human capital acquired in modern tertiary schools was especially valuable to a modern, industrial firm.

3.3.4 Earnings Differences Across Narrow Education Categories: Educational Content

I next explore whether particular modern educational *content* can be more tightly associated with the large salary premium associated with high levels of modern schooling. Specifically, I disaggregate modern tertiary education into three (exhaustive, mutually exclusive) categories: university training in engineering (35 individuals), university training in other subjects (85 individuals), and attendance at a teachers' college (24 individuals).

In addition to examining salaries associated with studying different content at the tertiary level in the modern education system, it is of interest to compare these salaries to those earned by individuals trained at a high level within the traditional system. This allows one to examine salary differences associated with differing content *within* the highest level of the modern system, and also *between* the high-level modern system and the high-level traditional system.

Using this content-based disaggregation of employees with high levels of schooling (educational categories $c \in \{$*modern university engineering, modern university non-engineering, modern teachers' college, high traditional*$\}$), I next estimate equation (1) on the sub-sample of employees educated at the tertiary level in the modern education system or at a high level in the traditional system. In Table 5, column 1, one can see estimated coefficients (relative to modern teachers' college, the omitted category) on the disaggregated educational content category dummies, from a model including quadratic controls for employee age and province of origin fixed effects. One can see, first, that engineering training at the

university level is associated with extremely high salaries. Salaries for university-trained engineers are around 50 percent larger than those of employees with university training in non-engineering fields, and over 100 percent larger than salaries of employees trained at a high level in the traditional system. While university study outside of engineering earns smaller premiums than engineering study, salaries are significantly higher for employees with university degrees in fields such as business, law and economics than for employees who studied at a high level of the traditional system or who studied at modern teachers' colleges. Finally, it is of interest that high levels of traditional education are associated with significantly higher salaries than study at modern teachers' colleges. This suggests that the higher salaries earned by employees trained at the tertiary level of the modern system, compared to those trained at high levels of the traditional system, are not simply a result of *more* schooling. Rather, the *content* studied seems to be an important determinant of the salary differentials observed.

In Table 5, column 2, I add to the specification in column 1 controls for tenure with the JinPu Railroad and prior experience, and the results are very similar to those in column 1: engineering training is associated with very high salaries; university training in fields other than engineering also earns a large premium, though smaller than engineering training; and, high-level traditional education is associated with a significantly smaller salary than modern university training, but a significantly larger salary than education in a teachers' college.

Table 5: Salary Differences Associated with the Content of Modern Tertiary Education

	Outcome variable: log(salary)			*MATCHING*		
	(1)	(2)	(3)	(4)	(5)	(6)
modern university engineering	1.060***	0.984***	1.044**	0.704***		0.373***
	[0.125]	[0.115]	[0.406]	[0.206]		[0.112]
modern university, not engineering	0.618***	0.535***	0.374		0.335***	
	[0.108]	[0.109]	[0.367]		[0.128]	
high traditional	0.217*	0.255**	-0.116			
	[0.125]	[0.128]	[0.367]			
modern teachers' college	omitted	omitted	omitted			
p-value: engineers=high trad.	≤ 0.001	≤ 0.001	≤ 0.001	0.001		
p-value: non-engineers=high trad.	0.010	0.021	0.006		0.009	
p-value: engineers=non-engineers	≤ 0.001	≤ 0.001	0.005			0.001
obs.	174	174	57	69	116	117
r-squared	0.53	0.62	0.52			
controls	quadratic age, province dummies	quadratic age, cubic tenure, province dummies, prior railroad exper, num. prior jobs	quadratic age, province dummies	quadratic age, province dummies	quadratic age, province dummies	quadratic age, province dummies
employees with high-level trad. and modern tertiary	all	all	age ≥ 40	univ. engineers or high traditional	univ. non-engineers or high trad.	all univ.

Note: Robust standard errors in brackets. Regressions have log salary as an outcome, a set of dummy variables for narrow education categories, and a set of controls. Columns 1-3 use OLS; columns 4–6 use nearest-neighbor matching. In column 4, the sample of individuals considered were educated at a high level in the traditional system or trained in engineering at the university level. In column 5, the sample of individuals considered were educated at a high level in the traditional system or trained in a subject other than engineering at the university level. In column 6, the sample of individuals considered were educated at the university level in the modern system, either in engineering or in other fields. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

In column 3, the model from Table 5, column 1, is estimated on the sub-sample of individuals aged 40 or greater who were educated at the tertiary level in the modern education system or at a high level in the traditional system. Results for the modern education categories are qualitatively similar to columns 1 and 2. However, the coefficient on the *high traditional* dummy is now negative (though it is not significantly different from zero). This result could be due to the small sample in this regression (there are only five employees with teachers' college educations aged 40 or older in the sample), or it could be a result of the scarce modern human capital among the older cohorts.

Next, in Table 5, column 4, I present the estimated treatment effect of university engineering education relative to high-level traditional education using a nearest-neighbor matching estimator (limiting the sample to employees educated in these two categories). One can see that university education in engineering is again associated with an economically and statistically significantly larger salary than high-level traditional education.

In Table 5, column 5, I estimate an analogous specification, but comparing *non*-engineering university training to high-level traditional education. One can see that studying subjects like business, economics, and law at a modern university earned a significant salary premium relative to high-level traditional education.

Finally, in Table 5, column 6, I present the treatment effect of engineering study relative to studying other fields at university. One can see that among individuals who studied in modern universities, those trained in engineering earned significant salary premiums.

The results in Table 5 indicate significant variation in salaries paid to the JinPu Railroad's employees associated with differing educational content. University training in engineering earned an especially large premium. High level education in the traditional system earned salaries above those of individuals educated in teachers' colleges, but significantly less than individuals educated in universities, again suggesting that educational

content played an important role in determining labor market outcomes.[35]

3.4 Occupation Differences

Differences in salaries provide evidence of employees' value to the JinPu Railroad, and so the value of different types of human capital; differences in occupations can provide complementary evidence of the tasks employees were relatively good at, and help clarify the mechanisms leading the Railroad to pay individuals with high-level modern (especially engineering) educations such high salaries. For example, finding that educational backgrounds *were not* associated with occupational differences might indicate that individuals with differing educational backgrounds simply had different outside options, which determined their pay at the JinPu Railroad. Finding that educational backgrounds *were* associated with differing occupations would be more consistent with salary differences being due to different skills produced by different educational content.

To study differences in occupational outcomes across individuals with different educational backgrounds, I construct a set of occupational categories based on railroad departments: *police*, *machine*, *road*, *clerical*, *train*, *hospital*, and *management*. The police department, unsurprisingly, policed the railroad lines, trains, stations, and property. The machine department managed and repaired the rolling stock of the railroad. The road department planned and managed the lines. The clerical department managed paperwork, accounts, and correspondence. The train department staffed stations and manned switches. The hospital is self-explanatory. And, the management department managed the affairs of the entire Railroad.

When analyzing employee occupations, I generally focus on the department in which

[35]It is reassuring that the results in Table 5 are robust to the inclusion of a wide range of controls, but one should keep in mind that selection on unobservables is of particular concern in this analysis: one must be concerned about selection into modern schooling; into higher levels of education; and, into the study of particular content.

an employee worked, simply assigning employees in a particular department to their own occupational category. The single exception to this assignment rule is that individuals with the specific occupational titles of "secretary" or "clerk", regardless of their department within the Railroad, are assigned to the "clerical" category, along with all employees in the clerical department. In general, I rely on Railroad departments, rather than specific occupational titles because the titles are often uninformative: for example, "Assistant" is an extremely common occupation within many departments.[36] In Table 6, I present summary statistics on the occupational categories.

Table 6: Summary Statistics for Occupational Categories

Occupational Category	Obs.	Mean	Number	No. Trad.	No. Modern	Ave. Salary
police	829	0.27	227	3	48	640.1
machine	829	0.33	270	15	177	998.5
roads	829	0.11	95	2	79	1110.3
clerical	829	0.19	158	22	112	1127.3
train	829	0.04	32	3	22	681.1
hospital	829	0.01	5	1	4	1812.0
managerial	829	0.05	42	0	38	1377.2

Note: Salary denominated in Chinese dollars. Average salary is provided for the individuals with a 1 for the relevant dummy variable and non-missing salary data.

3.4.1 Occupation Differences Across Broad Education Categories

To associate differences in educational backgrounds with differences in occupational outcomes, I estimate the following model:

$$Occupation\Gamma_i = \sum_c \psi_c Educ_{ci} + \phi Z_i + \eta_i \tag{2}$$

The outcome variable is simply a dummy variable equal to 1 if employee i is in occu-

[36] Using the departments as given (without re-assigning secretaries and clerks in non-clerical departments to the "clerical" category) does not change the results.

pational category Γ ($\Gamma \in \{police, machine, road, clerical, train, management\}$).[37] As in the analysis of salary differences, the explanatory variables of interest are a set of educational background dummy variables (with education category indexed by c). The model will also include a set of individual-specific controls (Z), namely, a quadratic function of age, and a set of province of origin dummies (so ϕ is a vector).[38]

I begin by estimating equation (1) using dummy variables for broad educational categories: *modern*, *traditional*, *military*, *apprenticeship*, and *police*. The *police* category is the omitted group. In Table 7, I present the results of estimating equation (2) for each occupational category.

One can see in Table 7, column 1, that as one would expect, individuals trained in both the traditional and modern education systems are significantly less likely than those trained in a police academy to be employed in the JinPu Railroad's police department. There is no difference in the likelihood of employment in the police department between the traditionally-educated and those educated in the modern system.

In Table 7, column 2, one can see that employees educated in the modern and traditional systems are both more likely to work in the machine department than are individuals trained in police academies. There is no significant difference between the traditionally-educated and those educated in the modern system in the likelihood of employment in the machine department.

In Table 7, column 3, one can see the first evidence of differing occupations between individuals trained in the modern and traditional education systems: individuals trained in the modern system are significantly more likely than individuals trained in the traditional

[37] In the analysis that follows I drop the hospital department from the analysis, due to its very small size.

[38] The analysis in this section is very similar if one includes in the model potentially endogenous controls for work experience and tenure at the JinPu Railroad. Results also are unaffected if one examines only employees aged 40 or older. Finally, estimating equation (2) using probit modes rather than OLS also produces very similar results. Thus, these robustness specifications are omitted for brevity. Results are available from the author upon request.

Table 7: Occupational Outcomes Across Broad Education Categories

	Occupation Category					
	Police	Machine	Road	Clerical	Train	Management
modern	-0.753***	0.373***	0.218***	0.069	0.027***	0.059***
	[0.046]	[0.032]	[0.032]	[0.046]	[0.010]	[0.014]
traditional	-0.719***	0.359***	0.006	0.299***	0.049	-0.013
	[0.061]	[0.071]	[0.045]	[0.083]	[0.037]	[0.012]
military	-0.089	0.069*	0.109***	-0.122**	0.022	0.013
	[0.066]	[0.038]	[0.042]	[0.056]	[0.025]	[0.023]
apprentice	-0.709***	0.893***	-0.043	-0.113**	-0.027**	-0.004
	[0.078]	[0.076]	[0.039]	[0.050]	[0.012]	[0.014]
police	omitted	omitted	omitted	omitted	omitted	omitted
p-value: modern=traditional	0.439	0.847	≤ 0.001	0.002	0.564	≤ 0.001
obs.	671	671	671	671	671	671
r-squared	0.49	0.20	0.15	0.13	0.08	0.06

Note: Robust standard errors in brackets. Each column represents an independent OLS regression with a dummy variable indicating that an employee has an occupation in the relevant category as the outcome variable. The explanatory variables are dummies for broad educational categories (with police education as the omitted comparison group), and controls for age (a quadratic polynomial) and a set of province of origin dummy variables. * p<0.1, ** p<0.05, *** p<0.01

system to be employed in the road department that planned and managed the lines of the JinPu Railroad.

One can next see that there were differences in the clerical department as well: in Table 7, column 4, one can see that traditionally-educated employees were significantly more likely than employees educated in the modern system to be employed in the clerical department. This disproportionate concentration of traditionally educated employees in the clerical department is consistent with their intense training in reading and writing, which were the necessary skills to be productive clerks.

In Table 7, column 5, one can see that there is no significant difference between the traditionally-educated and those educated in the modern system in the likelihood of employment in the train department.

Finally, in the highest-paid department (other than the very small hospital department), the managerial department, one can see that employees with modern education are sig-

nificantly more likely than are employees with traditional education. This suggests that despite the aims of the traditionally-educated to be high-level officials in the public sector, their skills did not naturally translate to managing a modern, industrial firm.

Overall, the findings in Table 7 of significant occupational differences between individuals trained in the modern and traditional systems are consistent with these educational institutions producing different types of human capital. It is next worth examining whether those educational backgrounds associated with the highest pay—modern university training, in particular in engineering—were associated with particular occupational outcomes.

3.4.2 Occupation Differences Across Levels of Education

I next examine how occupations varied across individuals educated at different levels of the modern and traditional systems. Using the disaggregation of the modern educational hierarchy and the traditional education system examined above ($c \in \{$*primary/middle, secondary, university/college, traditional high, traditional low*$\}$), I estimate equation (2) on the subsample of employees educated within the modern hierarchy or the traditional system.

In Table 8, column 1, one can see that there are no systematic differences in the prevalence of employees with high-level modern education and high-level traditional education in the police department. Modern university/college level education is slightly more common than high-level traditional education, and modern secondary education is slightly less common. In Table 8, column 2, one can see that there are not systematic differences in the machine department either.

In the road department, where there were systematic differences between broad modern and traditional education categories, one can see that this gap is driven both by there being significantly fewer traditionally-educated employees (low- and high-level), and by there being an especially large number of employees with tertiary education in the mod-

Table 8: Occupation Differences Across Levels of Traditional and Modern Schooling

	Occupation Category					
	Police	Machine	Road	Clerical	Train	Management
modern university/college	0.010	-0.106*	0.074*	0.023	-0.038*	0.022
	[0.043]	[0.060]	[0.043]	[0.052]	[0.021]	[0.030]
modern secondary	-0.102***	-0.129	-0.004	0.183**	0.019	-0.036
	[0.034]	[0.090]	[0.062]	[0.092]	[0.045]	[0.052]
high traditional	-0.052	-0.014	-0.116**	0.186**	0.042	-0.068***
	[0.037]	[0.091]	[0.053]	[0.090]	[0.054]	[0.021]
low traditional	0.182	-0.155	-0.221***	0.306**	-0.043	-0.057**
	[0.124]	[0.121]	[0.057]	[0.146]	[0.027]	[0.027]
modern primary/middle	omitted	omitted	omitted	omitted	omitted	omitted
p-value: univ.=high trad.	0.12	0.308	0.001	0.077	0.122	0.004
obs.	408	408	408	408	408	408
r-squared	0.08	0.12	0.11	0.14	0.12	0.05

Note: Robust standard errors in brackets. Each column represents an independent OLS regression with a dummy variable indicating that an employee has an occupation in the relevant category as the outcome variable. The explanatory variables are dummies for narrow educational categories (with modern primary/middle school education as the omitted comparison group), and controls for age (a quadratic polynomial) and a set of province of origin dummy variables. Regressions estimated using individuals educated in the modern hierarchy or the traditional education system.
* p<0.1, ** p<0.05, *** p<0.01

ern system (see Table 8, column 3). In the clerical department, one can see that there is a disproportionately large number of traditionally-educated workers (low- and high-level), relative to all modern education categories except secondary school (see Table 8, column 4).

In the train department, one can see that none of the educational categories is strongly associated with the occupation (see Table 8, column 5). Finally, in the management department, one can see that traditional education (low- and high-level) is broadly underrepresented relative to all of the modern education categories (see Table 8, column 6).

3.4.3 Occupation Differences Associated with Educational Content

I next explore whether particular educational *content* is associated with particular occupations. Using the content-based disaggregation of employees with high levels of schooling used above (educational categories $c \in \{$*modern university engineering, modern university*

non-engineering, modern teachers' college, high traditional}), I next estimate equation (2) on the sub-sample of employees educated at the tertiary level in the modern education system or at a high level in the traditional system.

In Table 9, column 1, one can see that engineers are especially unlikely to work in the police department, and that high-level traditional employees are also very unlikely to work as police. In Table 9, column 2, one can see that examining the content of education is extremely important to understanding occupational outcomes: while modern education, and particularly modern tertiary education, were not strongly associated with work in the machine department (managing the rolling stock), engineering training *is* strongly associated with the machine department.

Table 9: Occupation Differences Associated with the Content of Modern Tertiary Education

	Occupation Category					
	Police	Machine	Road	Clerical	Train	Management
modern univ. engineers	-0.314***	0.717***	0.117	-0.401***	-0.040	-0.089
	[0.104]	[0.103]	[0.095]	[0.116]	[0.031]	[0.079]
modern univ. non-engineers	-0.185*	0.077	0.140*	-0.081	0.000	0.014
	[0.102]	[0.072]	[0.074]	[0.116]	[0.028]	[0.089]
high traditional	-0.251***	0.355***	-0.100	0.034	0.066	-0.133*
	[0.097]	[0.106]	[0.086]	[0.135]	[0.054]	[0.077]
modern teachers' college	omitted	omitted	omitted	omitted	omitted	omitted
p-value: engineers=high trad.	0.176	0.005	0.037	≤ 0.001	0.056	0.264
p-value: non-engineers=high trad.	0.182	0.004	0.002	0.234	0.232	0.003
p-value: engineers=non-engineers	0.005	≤ 0.001	0.778	≤ 0.001	0.108	0.008
obs.	175	175	175	175	175	175
r-squared	0.19	0.43	0.14	0.21	0.13	0.14

Note: Robust standard errors in brackets. Each column represents an independent OLS regression with a dummy variable indicating that an employee has an occupation in the relevant category as the outcome variable. The explanatory variables are dummies for narrow educational categories (with education at a teachers' college as the omitted comparison group), and controls for age (a quadratic polynomial) and a set of province of origin dummy variables. Regressions estimated using individuals educated at the tertiary level in the modern hierarchy or at a high level in the traditional education system.
* p<0.1, ** p<0.05, *** p<0.01

Next, one can see that the positive association between modern (and particularly modern tertiary) education and work in the road department was driven by employees trained

at the university level both inside and outside of engineering (see Table 9, column 3). A link between educational content and occupation can very clearly be seen when examining the clerical department: one can see a highly significant and negative association between engineering study and working as a clerk (see Table 9, column 4).

In Table 9, column 5, one can see that none of the educational categories is strongly linked to work in the train department. Finally, one can see that high-level traditional education is negatively associated with a managerial occupation; interestingly, university training *outside* engineering (e.g., in law or economics) is significantly more common than university engineering training among the managers of the JinPu Railroad (see Table 9, column 6).

4 Discussion

In this subsection, I consider several concerns regarding the analysis of salary differences associated with different educational backgrounds. First, I evaluate the importance of combining salaried and graded workers. Second, I consider the role of variation in unobserved employee ability across educational categories. Finally, I discuss differences in the labor supply of individuals trained in the modern and traditional education systems.

4.1 Salaries and Pay Grades

As noted in Section 3.2, for two-thirds of the employees examined above, the JinPu Railroad's records contain specific information on salary; one-third of employees have a pay grade indicated in their record. In the analysis above, pay grades are converted into salaries using the mapping provided in the 1932 Railway Yearbook (*Tiedao Nianjian*), the earliest yearbook I could find with salaries matched to pay grades.

One might be concerned, however, about changes in wages across time leading the

salaries associated with pay grades in 1932 to be inflated relative to what those grades actually earned in 1929. If the likelihood of being a "graded" worker varied with educational background this could distort the analysis above. In fact, if one regresses a "graded worker" indicator variable on the educational categories examined above, one sees no significant difference in the likelihood of being a graded worker between employees with modern and traditional education overall, but one does see a significantly greater likelihood of being a graded worker among the university-educated in the modern system, especially among those trained in engineering.[39]

Table 10: Pay Grades and Salaries: Robustness of Salary Differences Across Broad Education Categories

	Outcome variable: log(salary)		
	(1)	(2)	(3)
modern	0.349***	0.313***	0.439***
	[0.037]	[0.043]	[0.088]
traditional	0.284***	0.305***	0.285**
	[0.066]	[0.085]	[0.112]
military	0.271***	0.242***	0.341***
	[0.055]	[0.070]	[0.109]
apprentice	0.369***	0.409***	0.297
	[0.077]	[0.079]	[0.190]
police	omitted	omitted	omitted
p-value: modern=traditional	0.314	0.928	0.109
obs.	665	429	236
r-squared	0.65	0.30	0.31
controls	quadratic age, province dummies grade indicator	quadratic age, province dummies	quadratic age, province dummies
employees included	all	salary only	grade only

Note: Robust standard errors in brackets. Regressions have log salary as an outcome, a set of dummy variables for broad education categories, and a set of controls. All columns estimated using OLS. Column 1 includes a dummy variable indicating whether an individual's employment record specified a salary or a grade, which is converted into a salary as described in the text. Column 2 is estimated using only individuals whose employment record specifies a salary. Column 3 is estimated using only individuals whose employment record specifies a grade, which is then converted to a salary.
* p<0.1, ** p<0.05, *** p<0.01

[39]These results are omitted for brevity and are available from the author upon request.

Table 11: Pay Grades and Salaries: Robustness of Salary Differences Associated with Educational Levels

	Outcome variable: log(salary)		
	(1)	(2)	(3)
modern university/college	0.253***	0.250***	0.212**
	[0.058]	[0.077]	[0.102]
modern secondary	0.132	0.215**	-0.207
	[0.084]	[0.099]	[0.170]
high traditional	0.094	0.092	0.039
	[0.071]	[0.086]	[0.140]
low traditional	-0.130	-0.185	-0.219
	[0.142]	[0.276]	[0.147]
modern primary/middle	omitted	omitted	omitted
p-value: university=high traditional	0.043	0.138	0.169
obs.	405	254	151
r-squared	0.66	0.35	0.37
controls	quadratic age, province dummies grade indicator	quadratic age, province dummies	quadratic age, province dummies
employees in traditional and modern hierarchy included	all	salary only	grade only

Note: Robust standard errors in brackets. Regressions have log salary as an outcome, a set of dummy variables for broad education categories, and a set of controls. All columns estimated with OLS using only individuals educated in the modern education hierarchy or in the traditional system. Column 1 includes a dummy variable indicating whether an individual's employment record specified a salary or a grade, which is converted into a salary as described in the text. Column 2 is estimated using only individuals whose employment record specifies a salary (among those educated in the modern hierarchy or traditional system). Column 3 is estimated using only individuals whose employment record specifies a grade (among those educated in the modern hierarchy or traditional system), which is then converted to a salary. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

To examine whether combining graded and ungraded workers drives the salary differences across educational categories, I first estimate models that add a "graded employee" dummy variable as a control variable to the specifications of equation (1) examined above (in addition to controls for a quadratic in employee age and province fixed effects). If there were a single inflation adjustment that should be applied to graded workers' salaries, this control variable would be sufficient.

One can see in the first columns of Tables 10–12 that the findings above are not affected by inclusion of the "graded worker" control. There is still little difference in salaries be-

Table 12: Pay Grades and Salaries: Robustness of Salary Differences Associated with Educational Content

	Outcome variable: log(salary)		
	(1)	(2)	(3)
modern university engineering	0.738***	0.666***	0.677***
	[0.112]	[0.249]	[0.162]
modern university, not engineering	0.490***	0.573***	0.434***
	[0.094]	[0.168]	[0.144]
high traditional	0.214**	0.216	0.260
	[0.100]	[0.140]	[0.179]
modern teachers' college	omitted	omitted	omitted
p-value: engineers=high trad.	≤ 0.001	0.076	0.006
p-value: non-engineers=high trad.	0.005	0.017	0.207
p-value: engineers=non-engineers	0.005	0.645	0.023
obs.	174	70	104
r-squared	0.66	0.47	0.45
controls	quadratic age, province dummies grade indicator	quadratic age, province dummies	quadratic age, province dummies
employees with high-level trad. and modern tertiary	all	salary only	grade only

Note: Robust standard errors in brackets. Regressions have log salary as an outcome, a set of dummy variables for broad education categories, and a set of controls. All columns estimated with OLS using only individuals educated at the tertiary level in the modern system or at a high level in the traditional system. Column 1 includes a dummy variable indicating whether an individual's employment record specified a salary or a grade, which is converted into a salary as described in the text. Column 2 is estimated using only individuals whose employment record specifies a salary (among those educated at the tertiary level in the modern system or at a high level in the traditional system). Column 3 is estimated using only individuals whose employment record specifies a grade (among those educated at the tertiary level in the modern system or at a high level in the traditional system), which is then converted to a salary. * p<0.1, ** p<0.05, *** p<0.01

tween broad categories of traditionally-educated employees and employees educated in the modern system (Table 10, column 1, compared to Table 3, column 2). There is still a large difference between university/college education in the modern system and high-level traditional education (Table 11, column 1, compared to Table 4, column 1). And, there are still large salary premiums paid to university training, especially in engineering, compared to high-level traditional education (Table 12, column 1, compared to Table 5, column 1).

As another check of the role played by combining graded and salaried workers, I can

conduct the analyses above, but splitting the sample between salaried and graded workers. In the second columns of Tables 10–12, one can see results for only workers earning salaries in the JinPu Railroad employee records, and in the third columns of Tables 10–12, one can see results for only graded workers.

Again one can see that the comparative findings across educational categories above were not driven by the combination of salaried and graded workers (although some magnitudes are somewhat different). Whether examining only salaried workers or only graded workers, there is no statistically significant difference in salaries (imputed salaries in the case of the graded workers) paid to employees from the broad traditional or broad modern education categories (Table 10, columns 2–3 compared to each other, and compared to Table 3, column 2).[40] Whether examining only salaried workers or only graded workers, one sees not-quite statistically significantly higher salaries paid to employees who studied in modern university/college than to employees trained at a high level in the traditional system (Table 11, columns 2–3 compared to each other, and compared to Table 4, column 1). Finally, examining either salaried workers or graded workers, one can see statistically significant salary premiums associated with university engineering training, very high salaries paid to employees trained in universities in subjects other than engineering, and smaller premiums paid to individuals trained at a high level of the traditional system (Table 12, columns 2–3 compared to each other, and compared to Table 5, column 1).

4.2 Variation in Unobserved Ability

A standard concern in regressions linking earnings to educational attainment is that educational attainment is correlated with unobserved ability, which itself helps to determine earnings. In comparing traditional and modern education, historical evidence suggests

[40]There is a difference in salaries on the margin of statistical significance among the graded employees.

that selection into the traditional system was by the more able, due to its greater prestige. Elman (2006, p. 158) describes the graduates of the modern system as "considered marginal because they usually had failed the more prestigious civil examinations." Even later in the 19th century, after the Qing government began incorporating individuals with training in modern subjects into the bureaucracy, individuals with modern training were at "lower levels of political rank, cultural distinction, and social esteem" (Elman, 2006, p. 195). Bai (2014) shows that there was greater study of modern subjects abroad immediately following the abolition of the civil service exams in 1905, and that the individuals who moved into modern study were more able than those studying modern subjects before, providing further evidence that the traditional education system (when operative) attracted higher ability individuals than the modern system. This sort of positive selection into the traditional system would drive up the estimated return to traditional education, especially among the early cohorts; it may explain why the return looks as high as it does, but it does not explain the huge gap between traditional education and university or engineering training.

Finally, the analysis above of employees at least age 40 (compared to the broader sample) also suggests that selection on ability into educational tracks is not the primary determinant of earnings differences across educational categories. Historical evidence (as noted above) is abundant indicating more able types studied in the traditional system prior to its abolition. However, if anything, traditional education is associated with relatively *lower* salaries among the oldest cohorts in the JinPu Railroad. This suggests that relative supply of skills (traditional education was more abundant among the older cohorts in the sample), rather than selection is a larger determinant of salaries.[41]

[41] Another possibility is that even if individuals trained in the traditional system were positively selected on average, perhaps only the least able of them selected into working in modern firms such as railroads. Historically, working in teaching or government was much more closely associated with the traditionally-educated. However, historians have documented far more frequent entry of traditionally-educated gentry into the private sector beginning in the late 19th century (see Chang, 1955, 1962), especially after the abolition of the civil service exams in 1905.

4.3 Variation in Labor Supply

A final concern is that variation in labor supply across individuals with differing skills may explain the results above. The most basic question is one of relative supply of individuals with traditional and modern education. By the late 1920s, the supply of training in modern, Western subjects had already greatly expanded, coming from Chinese schools, especially in treaty ports and cities with missionary presence, and from study abroad (Yan, 2007; Bai, 2014; Jia, 2014; Bai and Kung, forthcoming). By the late 1920s there were far fewer individuals with high-level traditional education, as the civil service exams had already been abolished for 15 years. Thus, the higher wages among the university-trained, especially the engineers (relative to those trained at a high level in the traditional system) do not seem likely to arise from relative supply differences.

One might wonder if labor market "frictions" varied across individuals with differing educational backgrounds. For example, personnel policies in modern firms might have systematically treated traditionally-educated individuals differently. Perhaps traditionally-educated workers are concentrated in the clerical department because similarly-trained individuals might have certain positive complementary effects (they use the same jargon, etc.). This seems unlikely to be the case, however: the majority of employees in the clerical department in the JinPu Railroad were actually trained in the *modern* system; but, the traditionally-educated were disproportionately working there. Thus, traditionally-educated workers were not, based on hiring policies at the railroad, concentrated in their own (low-wage) department. They worked alongside those trained in the modern system, but not in some of the highest paying departments.

Another possibility is that traditionally-educated workers had poorer outside options, and so were paid less than those educated in the modern system despite being equally productive. However, within the clerical department, individuals trained at a high level in the

traditional system earned wages that were *not* significantly different from those trained in modern universities (the salary gap drops from 40 percent across all departments to under 18 percent within the clerical department). At the high-end of the salary distribution, the highest-earning traditionally-educated worker earned 95 percent as much as the highest-paid employee trained in the modern system, again suggesting that there was not discrimination in wages across educational backgrounds. This suggests that supply differences and differences in labor market frictions did not lead to pay differences for the same tasks. Rather, differences in productivity arising from human capital differences seem the most likely source of occupational and salary differences across employees.

5 Conclusion

The JinPu Railroad's employee records provide some of the first evidence of the effects of both modern and traditional education in a modern firm at an early stage of industrialization. The systematic differences in labor market outcomes between individuals trained in China's traditional and modern educational tracks suggest that traditional and modern schools produced types of human capital that were differentially productive in a modern, industrial firm. Chinese reformers around the turn of the 20th century were thus correct in believing that modern, Western education could provide especially useful skills for a developing economy that was adopting new technologies from abroad. These findings indicate that beyond years of schooling, the *content* of schooling can play an important role in the process of economic development.

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References

Altonji, Joseph G., Erica Blom, and Costas Meghir, "Heterogeneity in Human Capital Investments: High School Curriculum, College Major, and Careers," April 2012. NBER Working Paper 17985.

Ashraf, Quamrul and Oded Galor, "The'Out of Africa' Hypothesis, Human Genetic Diversity, and Comparative Economic Development," *American Economic Review*, 2013, *103* (1), 1–46.

Bai, Ying, "Farewell to Confucianism: The Modernizing E ect of Dismantling China's Imperial Examination System," October 2014. Unpublished, Hong Kong University of Science and Technology.

__ **and James Kai-sing Kung**, "Diffusing Useful Knowledge while Spreading God's Message: Protestantism and Economic Prosperity in China, 1840–1920," *Journal of the European Economic Association*, forthcoming.

Barro, Robert J., "Economic Growth in a Cross Section of Countries," *The Quarterly Journal of Economics*, 1991, *106* (2), 407–443.

Baten, Joerg, Debin Ma, Stephen Morgan, and Qing Wang, "Evolution of living standards and human capital in China in the 18–20th centuries: Evidences from real wages, age-heaping, and anthropometrics," *Explorations in Economic History*, 2010, *47* (3), 347–359.

Brandt, Loren, Debin Ma, and Thomas G. Rawski, "From Divergence to Convergence: Re-evaluating the History Behind China's Economic Boom," *Journal of Economic Literature*, 2014, *52* (1), 45–123.

Cantoni, Davide and Noam Yuchtman, "The Political Economy of Educational Content and Development: Lessons from History," *Journal of Development Economics*, 2013, *104*, 233–244.

__ **and** __ , "Medieval Universities, Legal Institutions, and the Commercial Revolution," *Quarterly Journal of Economics*, 2014, *129* (2), forthcoming.

Chaffee, John W., *The Thorny Gates of Learning in Sung China: A Social History of Examinations*, Albany, NY: State University of New York Press, 1995.

Chang, Chung-li, *The Chinese Gentry: Studies on their Role in Nineteenth-Century Chinese Society*, Seattle: University of Washington Press, 1955.

__ , *The Income of the Chinese Gentry*, Seattle: University of Washington Press, 1962.

Chang, Jui-te, "Technology Transfer in Modern China: The Case of Railway Enterprise (1876-1937)," *Modern Asian Studies*, 1993, *27* (2), 281–296.

Chen, Yuyu, Hui Wang, and Se Yan, "The Long-Term Effects of Protestant Activities in China," January 2014. Working Paper, Peking University.

Coleman, D. C., "Gentlemen and Players," *The Economic History Review*, 1973, *26* (1), 92–116.

Elman, Benjamin A., *A Cultural History of Civil Examinations in Late Imperial China*, Berkeley: University of California Press, 2000.

_ , *A Cultural History of Modern Science in Late Imperial China*, Cambridge, Mass.: Harvard University Press, 2006.

Galor, Oded and David N. Weil, "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond," *American Economic Review*, 2000, *90* (4), 806–828.

_ **and Omer Moav**, "Das Human-Kapital: A Theory of the Demise of the Class Structure," *Review of Economic Studies*, 2006, *73* (1), 85–117.

Glaeser, Edward L., Rafael La Porta, Florencio Lopez de Silanes, and Andrei Shleifer, "Do Institutions Cause Growth?," *Journal of Economic Growth*, 2004, *9*, 271–303.

Goldin, Claudia and Lawrence F. Katz, "Education and Income in the Early 20th Century: Evidence from the Prairies," *Journal of Economic History*, 2000, *60*, 782–818.

_ **and** _ , *The Race Between Education and Technology*, Cambridge, MA: Harvard University Press, 2010.

Hanushek, Eric A. and Dennis D. Kimko, "Schooling, Labor-Force Quality, and the Growth of Nations," *American Economic Review*, 2000, *90* (5), 1184–1208.

Headland, Isaac Taylor, *Court Life in China: The Capital, its Officials and People*, Champaign, IL: Project Gutenberg, n.d.

Heckman, James J., Jora Stixrud, and Sergio Urzua, "The Effects of Cognitive and Noncognitive Abilities on Labor Market Outcomes and Social Behavior," *Journal of Labor Economics*, 2006, *24* (3), 411–482.

Ho, Ping-ti, *The Ladder of Success in Imperial China*, New York: Columbia University Press, 1962.

Hoffman, Philip T., "Why Was It Europeans Who Conquered the World?," *Journal of Economic History*, September 2012, *72* (3), 601–633.

Hon, Tze-Ki, "Zhang Zhidong's Proposal for Reform: A New Reading of the Quanxue *pian*," in Rebecca E. Karl and Peter Zarrow, eds., *Rethinking the Reform Period. Political and Cultural Change in Late Qing China*, Cambridge, Mass.: Harvard University Press, 2002, chapter 3, pp. 77–98.

Huff, Toby E., *The Rise of Early Modern Science. Islam, China and the West*, Cambridge: Cambridge University Press, 2003.

Jia, Ruixue, "The Legacies of Forced Freedom: China's Treaty Ports," *Review of Economics and Statistics*, 2014, *124*, 92–118.

Jones, Benjamin F., "The Knowledge Trap: Human Capital and Development Reconsidered," September 2014. Northwestern University, Unpublished.

Karl, Rebecca E. and Peter Gue Zarrow, *Rethinking the 1898 Reform Period: Political and Cultural Change in late Qing China*, Vol. 214 of *Harvard East Asian monographs*, Cambridge, Mass.: Harvard University Asia Center, 2002.

Köll, Elisabeth, "Chinese Railroads, Local Society, and Foreign Presence: The Tianjin-Pukou Line in pre-1949 Shandong," in Bruce A. Elleman and Stephen Kotkin, eds., *Rivers of Steel: Manchurian Railways and Chinese Development, An International Perspective*, Armonk, NY: M.E. Sharpe, 2009.

Lin, Justin Yifu, "The Needham Puzzle: Why the Industrial Revolution Did Not Originate in China," *Economic Development and Cultural Change*, 1995, *43* (2), 269–292.

Ma, Debin, "Why Japan, not China, Was the First to Develop in East Asia, Lessons from Sericulture 1850-1937," *Economic Development and Cultural Change*, 2004, *52* (2), 369–394.

_ , "Law and Commerce in Traditional China, an Institutional Perspective on the Great Divergence," *Keizai-Shirin*, 2006, *73* (4).

_ , "Economic Growth in the Lower Yangzi Region of China in 1911–1937: A Quantitative and Historical Analysis," *Journal of Economic History*, June 2008, *68* (2), 355–392.

Mankiw, N. Gregory, David Romer, and David N. Weil, "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics*, May 1992, *107* (2), 407–437.

Mincer, Jacob, *Schooling, Experience, and Earnings*, New York: NBER Press, 1974.

Miyazaki, Ichisada, *China's Examination Hell: The Civil Service Examinations of Imperial China*, New Haven: Yale University Press, 1981.

Mokyr, Joel, *The Lever of Riches: Technological Creativity and Economic Progress*, New York: Oxford University Press, 1990.

Morgan, Stephen L., "Personnel Discipline and Industrial Relations on the Railways of Republican China," *Australian Journal of Politics and History*, 2001, *47* (1), 24–38.

Morris, Ian, *Why the West Rules...For Now*, New York: Farrar, Straus and Giroux, 2010.

Pomeranz, Kenneth, *The Great Divergence: China, Europe and the Making of the Modern World*, Princeton, NJ: Princeton University Press, 2000.

Rawski, Evelyn S., *Education and Popular Literacy in Ch'ing China*, Ann Arbor, MI: University of Michigan Press, 1979.

Rawski, Thomas G., *Economic Growth in Prewar China*, Berkeley: University of California Press, 1989.

Rosenthal, Jean- Laurent and R. Bin Wong, *Before and Beyond Divergence*, Cambridge, Mass.: Harvard University Press, 2011.

Roy, A.D., "Some Thoughts on the Distribution of Earnings," *Oxford Economic Papers, New Series*, June 1951, *3* (2), 135–146.

Sng, Tuan-Hwee and Chiaki Moriguchi, "Asia's Little Divergence: State Capacity in China and Japan Before 1850," *Journal of Economic Growth*, December 2014, *19* (4), 439–470.

Squicciarini, Mara P. and Nico Voigländer, "Human Capital and Industrialization: Theory and Evidence from the Enlightenment," March 2014. Working Paper, UCLA.

Weston, Timothy B., "The Founding of the Imperial University and the Emergence of Chinese Modernity," in Rebecca E. Karl and Peter Zarrow, eds., *Rethinking the Reform Period. Political and Cultural Change in Late Qing China*, Cambridge, Mass.: Harvard University Press, 2002, chapter 4, pp. 99–123.

Wright, Mary C., *China in Revolution*, New Haven: Yale University Press, 1968.

Yan, Se, "Real Wages and Skill Premia in China, 1858-1936, Evidence from the China Maritime Customs Archives," 2007. Manuscript.

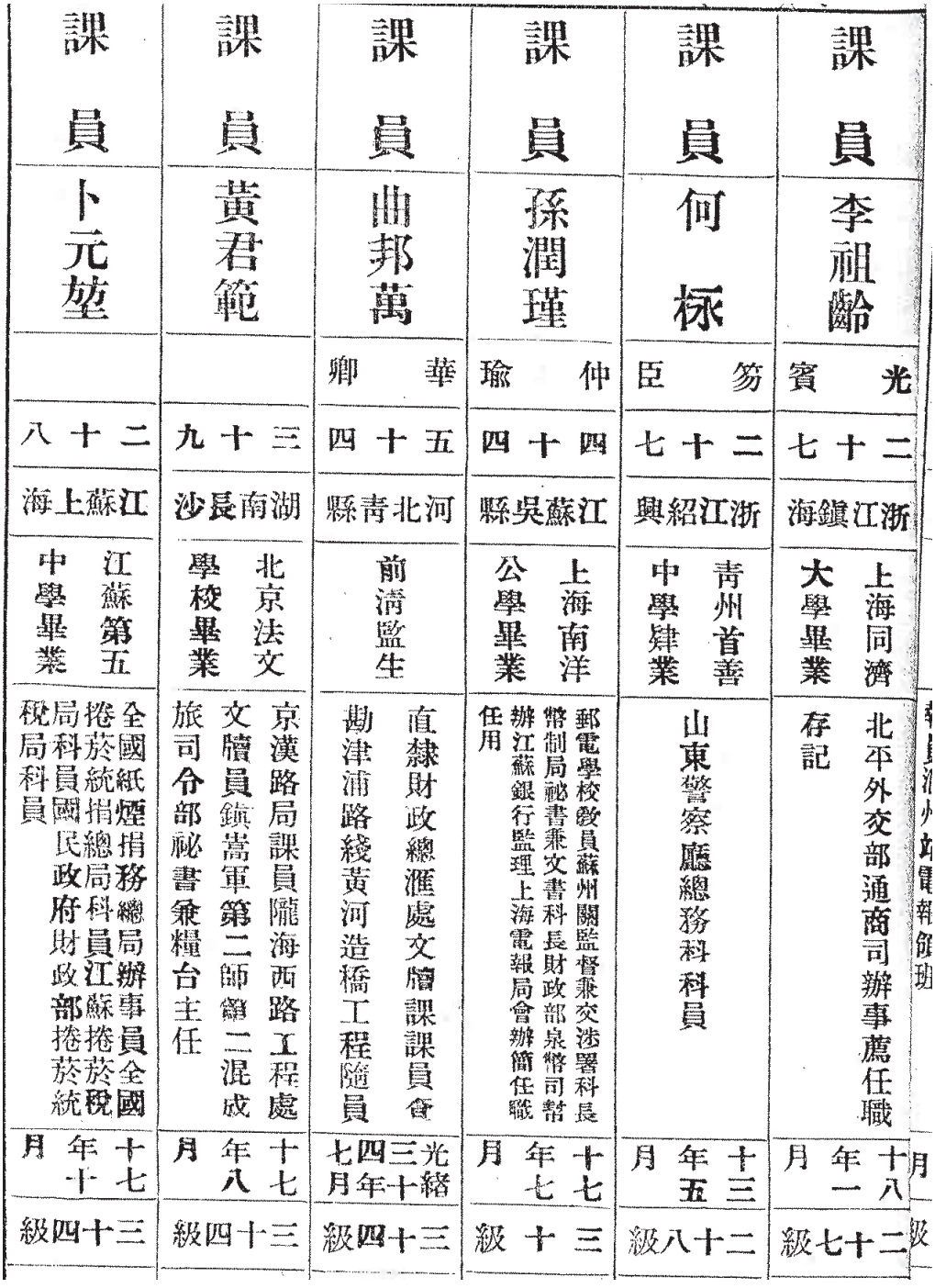

Figure A.1: Page from the JinPu employee records.