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Research Paper

Confucianism and science ☆

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ABSTRACT

China made phenomenal progress in science and technology during the long twentieth century. However, in the literature, there are contrasting opinions on the role Confucianism played here. To answer the question regarding whether Confucianism served as a stumbling block or a stepping stone, we must first disentangle some of the multifaceted connotations of "Confucianism," such as its worldviews, learning traditions, and "the teaching of Confucius" in a religious sense. The sectarian division of Confucian learning, particularly Neo-Confucianism and evidential learning, which corresponded to Song learning and revived Han learning in the Qing context, respectively, is given special consideration. We exploit several rare datasets of scientists and engineers for the era of the modern period and contemporary times, as well as data on the first wave of the new-style schools, measures of Neo-Confucianism, and the spatial distribution of prolific evidential scholars. We then show that the accumulation of human capital due to the imperial examination system and evidential scholarship contributed to the rise of modern science in China, whereas Confucian values as represented by various Neo-Confucian measures did not.

1. Introduction

Over the past few decades, China has reached and, in some cases, expanded the world's science and technology frontiers. What are the causes of this rapid progress? In recent years, a growing number of articles attribute China's recent scientific achievements to Confucian values often coined as Confucianism (e.g., Tu, 1996; Du, 2003; He, 2018; Zurndorfer, 2018; Wong, 2020, etc.). In contrast, the traditional human capital interpretation attributes both public and private investments in science education to China's rise in science and technology (e.g., Xie, Zhang, and Lai, 2014). The literature has not addressed the relationship between human capital and cultural interpretations of China's scientific achievements in the long twentieth century. Inasmuch as Confucianism indirectly contributes to scientific progress by fostering human capital, this relationship may be complex, as its ethics may also work against it.

It is widely acknowledged that the notion of 'Confucianism' is multifaceted, as the term can refer to Confucian worldviews, learning traditions, and 'the teaching of Confucius' in a religious context.[1] Contrary to other major faiths, Confucianism has a strong underpinning in education, as the imperial examination regime served as the cornerstone of the meritocracy throughout much of

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[1] Jensen (1977) even contends that Confucianism did not exist until Jesuits in the sixteenth century and Chinese scholars in the early twentieth century created it. Cai (2015) argues that interpreting the Confucian tradition as creating it began as early as Confucius' immediate disciples and its versatile tradition allowed scholars throughout history to transform Confucianism into a school of thought, a political ideology, an ethics, and a religion.

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the imperial time. This makes the wholesale use of the concept of Confucianism problematic because, on the one hand, the stylized Confucian ethics such as the emphasis of chastity, the filial piety and fraternal duty within a patriarchal clan, and abstinence etc., emerged during the Song dynasty and had been endorsed by the imperial state ever since known as the Neo-Confucianism, represent the commonly understood Confucian culture; on the other hand, the Confucian learning often measured by those who earned high achievements in the imperial examinations such as the *jinshi* (presented scholar) indeed represents the level of educational attainment. Relevant studies are further complicated by the rise of evidential learning in late imperial times as the resurrected Han learning which employed a variety of approaches scientific in nature.[2]

In this study, we examine the role of Confucianism played in the early development of modern science in China by entertaining several rare datasets that were unexplored by the literature previously. Rudimentarily, the vigor of both Neo-Confucian ethics and learning traditions in a locality is influenced by the abecedarian Confucian learning institutions, which are often measured by their *shengyuan* (those who have passed the entry-level imperial exam) quota as entry level admission caps in the imperial examination system. Our back-of-the-envelope OLS regressions running from quota to modern time and contemporary STEM (science, technology, engineering, and mathematics) talents suggest a strong positive association. However, the statistical significance of quotas on modern time STEM talents (1930s) is lost when we implement the 2SLS procedure, implying that the effect of *shengyuan* quotas on modern science could be ambiguous.[3] We then regress new-style school over quota and STEM talents over new-style schools, and the results indicate a clear-cut causal relationship. To isolate the effect of Confucian culture, we regress Neo-Confucian variables over quota and science over Neo-Confucianism. In both OLS and 2SLS regressions, the results show that quota was strongly causal on Neo-Confucian ethics but the link from Neo-Confucianism to modern science was broken. By contrast, the effect of historical human capital represented by *jinshi* and evidential scholars on modern science was pronounced. Overall, we show that instead of the effect of Confucian culture measured by Neo-Confucian ethics such as recorded chastity, preserved family genealogy books, and the spatial distribution of historical Neo-Confucian academies, historical human capital measured by the numbers of *jinshi* and evidential scholarship contributed to the rise of modern science in China, supporting the role of human capital in the development of science found in the literature (e.g., Waldinger, 2010, 2016; Borjas and Doran, 2012; Hvide and Jones, 2018).

The current article relates to an important and interdisciplinary literature, even when confined to Chinese religion and science alone. Most notably, the publication of Joseph Needham's monumental work *Science and Civilisation in China* has set the tone of Chinese culture on its (under-) development of science. In Needham's words, "Why did modern science, the mathematization of hypotheses about Nature, with all its implications for advanced technology, take its meteoric rise only in the West at the time of Galileo?", and why it "had not developed in Chinese civilization" which in the previous many centuries "was much more efficient than occidental in applying" natural knowledge to practical needs? Needham ascribed China's stagnation of science to Confucianism (Needham, 1956). To him, the answer is rather straightforward, i.e., Confucius and his followers in the next two millennia were not interested in discussing natural phenomena since they were disconnected from ethical, moral, or social problems. Needham's claim was echoed by Max Weber's 'China thesis' which negates the role of Confucianism in China's modernization. Indeed, Weber (1951) contended that Confucianism, as the ruling ideology, prevented China from modernizing due to its absence of moral imperatives as the tension in the ascetic Protestantism.

Likewise, western historians adhering to the Wright-Fairbank framework attribute a detrimental role to Confucianism in China's modernization initiatives. Wright (1957) argued that the Tongzhi Restoration was a golden opportunity to modernize China and it turned out quite successful at the beginning against a series of negative factors such as Western intrusion, popular revolt, and financial restraints. The failure of the Restoration was the opposition of the Confucians in the government who saw the development of railroads, telegraphs, and modern industries as a threat to traditional society. Similarly, John King Fairbank's 'impact-response' paradigm emphasizes the importance of the impact of the West and attributes the failure to China's internal factors such as Confucian ideals which take the blame.

However, the recent growing literature in economics claiming a positive effect of Confucian culture on China's economic development in recent decades seems to put the dominant Fairbankian paradigm and Needham puzzle at fundamental odds (see, e.g., Macfarquhar, 1980; Tu, 1996; Du, 2003; He, 2018; Zurndorfer, 2018; Xu and Li, 2019, etc.). The drawbacks of recent economics literature are apparent: the contemporary statistics and their explanatory variables such as Confucian temples are only loosely connected, if they are connected at all, since sacrificial rituals for Confucian sages ceased a long time ago and the religious remnants of Confucianism disappeared in their entirety. The second problem with these studies is that they often do not distinguish concepts like Confucian ethical values, Confucian learning traditions, and secondary notions derived from Confucian learning such as the human capital accrued as a byproduct of the imperial examination system (*keju*).

Thus, the question about whether Confucianism stood in the way of science or served as a facilitator shall be presented with caution: indeed, it is what aspects of the so-called Confucianism facilitated the development of science and which did not. We show

[2] A revival of Han learning (or evidential learning) aimed to replace the metaphysical speculation of the Song learning began to equip with a more solid foundation by using rigorous and objective approaches that were immune from contemporary ideological biases. The methodologies that Qing evidential scholars developed or promoted included philology, phonetics, etymology, and textual collation and criticism. Diverse sources, ranging from incomplete documents to the oracle, bronze, and stone inscriptions, were utilized to arrive at an understanding of the true meaning of the classics. Although evidential learning is on many occasions equalized to Han Learning, scholars during the Han dynasty never used these 'scientific' approaches to such an intensive degree.

[3] This is precisely our point in this paper, i.e., the indiscriminate application of Confucianism by including its worldview and learning traditions does not lend us useful insights to the debate. Since *Shengyuan* quota encompasses all aspects of Confucianism, the insignificant result may imply that the facilitating role of its embedded human capital and the impeditive role of its ethics may had acted as two countervailing forces.

that the historical quota institution paved the way for the spreading of the new-style schooling and consequently the aforementioned modern STEM talents. Most notably, the channel through which the positive impact of quotas took effect stemmed from historical human capital and evidential learning tradition rather than the Neo-Confucian values. In terms of magnitude, doubling the quantity of human capital measured by *jinshi* and evidential scholar correspond respectively to the increases of 21.5% and 15.4% of new-style schools. To address the potential endogeneity issue, we use two instrumental variables (IV) suggested by Bai and Jia (2016), namely, the number of small rivers normalized by the total length of rivers and the first difference of exam performance between the two periods preceding the establishment of the quota system. Our baseline results are validated by the instrumented results. As a last robustness check, we employ the number of students enrolled in new-style schools as an alternative measure of new-style learning, and the results confirm the benchmark results. In particular, our results on the role of evidential scholarship suggest that the Fairbankian paradigm view which prescribes every single Chinese progress as a response to the West's impulse may have overlooked China's internal impetus albeit feeble at the beginning.

Our findings contribute to the recent literature suggesting a human capital interpretation of scientific development (e.g., Borjas and Doran; 2012; Hvide and Jones; 2018; Waldinger, 2016). Our argument that the Confucian learning traditions are a deep root of modernity is consistent with Waldinger's (2010) claim that human capital persists through intergenerational transmission. Notably, we show that the Confucianist meritocracy aided the historical accumulation of human capital, which had a long-lasting effect, i.e., the legacy of the quota system through the lens of human capital accumulation benefited contemporary scientific endeavors. In contrast, we find no support for the cultural interpretation that the Neo-Confucian ethics, as the working Confucian values in the late imperial context, were favourable to the spread of modern science. Our paper then echoes Becker and Woessman (2009) who do not support the effect of Protestant ethics on the rise of capitalism but do support a strong positive role of human capital as an unintended outcome.

The remainder of this article proceeds as follows. Section 2 articulates the conceptual issues in the so-called Confucianism and its factions, with a focus on the context of late imperial China. Section 3 introduces the empirical model and data. Section 4 reports and explains the empirical results. Section 5 concludes.

2. Background

The vagueness of the name 'Confucianism' itself is a significant concern in international literature. "Confucianism" on most occasions stands for *Ruxue* with the inclusion of Neo-Confucianism (*Xin ruxue*), to describe classical learning (*jingxue*) in imperial China. This interpretation coincides with the Chinese literature, so discussions can be on the same page. But it can also be understood as a set of worldviews and moral norms stipulated by the Confucian classics. There is often a third understanding in religious terms, i.e., Confucianism as *Kongjiao*, or literally 'the teaching of Confucius' or 'the religion of Confucius'. Although one should not underestimate the moral faith a traditional literati attaches to Confucian orthodoxy and the teachings of the Confucian canon, it is misleading to envisage Confucianism on par with a typical transcendent religion such as Christianity.[4] Efforts in escalating Confucianism into a formal religion by Kang Youwei were unsuccessful, reflecting the discontent of the populous and the literati with this religious transformation. Indeed, the Qing dynasty witnessed a series of intensified strife among different Confucian factions, notably the expulsion of Ming learning (the Learning of Heart-and-Mind) was out of the Confucian orthodoxy by the Song learning (learning of way), and the rise of Han learning (evidential studies) to replace the Song learning's *de facto* dominance in scholarly life.

From the late Ming dynasty to the end of the Qing dynasty, Confucian scholars went through a long and painstaking procedure to reform Confucianism in terms of classical learning. During the time of Confucius in the sixth century BCE, multiple competing schools of thought coexisted. By the time of the Han empire (206 B.C. to circa 220 A.D.), the theories of Confucius and his disciples had become the state ideology. The Han learning of Han Studies (*Hanxue*) refers to the Han school of classical philology which relied exclusively on the originals of the transmitted Confucian classics that were created during the Han period and carried over to Jin until the Tang dynasty. The essence of Han learning is the philosophical efforts that primarily employed philological techniques to comprehend Confucian literature (*xungu*). The renaissance of Han learning began during the late Ming dynasty and flourished throughout the late Qing dynasty.

The second school is the Song learning or Learning of Principles (*Lixue*) as a moral, ethical, and metaphysical Confucian philosophy, often based on Zhu Xi (1130-1200 A.D.)'s hermeneutics or the interpretations of the Four Books, namely, the Analects of Confucius; Mencius; Great Learning; and the Doctrine of Mean. Zhu's interpretation of the Confucian canon became the basis of the imperial examination in 1313, establishing him as the authoritative spokesman for the entire *Daoxue* (Learning of the Way) tradition. Zhu's research area covered a whole range of topics but his best-known claims which also fundamentally shaped Song learning is the concept of *neixing* (introspection) which was extended to the self-restraint of undue desires and *gewu zhizhi* (investigation of things and extension of knowledge).

The third school is the Learning of the Heart-and-Mind (*xinxue*), sometimes known as the Lu-Wang school for its two most influential proponents, notably Wang Yangming. It was opposed to the other great (and dominant) school, the Song Learning, since Wang broke with orthodoxy on some fundamental issues, most notably by because Wang broke with orthodoxy on some fundamental issues, most notably by asserting that personal experience and intuition through ethical cultivation can make the heart-and-mind a constituent of the principles (*li*) as the source of heavenly order and moral virtue. Despite the fact that both the Song learning

[4] The conceptualization of Confucianism as a world religion was a historical product of the 'world religions' paradigm in the West at the end of the nineteenth century in Europe. (Sun, 2013)

and Lu-Wang schools adhere to what has been termed "Neo-Confucianism," they differ significantly in their interpretation of nature. Despite the fact that both emphasized the praxis of self-cultivation for ultimate moral axiology, the Song Learning represented by Zhu Xi preferred *gewu* or investigation of things, whereas the Learning of Heart-and-Mind proposed *jingzuo* (meditation), a practice that strongly resembles Chan (Zen) Buddhist meditation to achieve an innate faculty of moral understanding that Wang Yangming called *liangzhi* which can be loosely translated as "innate knowledge" or "conscience" and can be comparable with Kant's notion of intuitive knowledge. In his celebrated article '*Why China has no Science*?', Fung (1922) summarizes that while Europeans developed techniques for understanding and controlling matter, the Chinese Neo-Confucians developed techniques for understanding and controlling the mind.

From the demise of *Xinxue* to the monopoly of *Songxue* and finally to the resurgence of *Hanxue*, the Ming and Qing Dynasties underwent a progression. The infamous fall of capital to rebellion leader Li Zicheng and subsequent defeat by the Manchus sparked a surge of introspection among Confucian scholars regarding the potential failure of the ever-evolving Confucian principles as the state orthodoxy. The Han learning began with the "evidential scholarship" (*kaoju*) movement of the late Ming dynasty, which was a reaction against the so-called "Song Learning" that depended solely on Zhu Xi's hermeneutics. One major effort of the evidential scholars was to employ philological techniques to authenticate the classics of Confucius. This required a detailed comparison of various texts, as well as the use of later archaeological discoveries as important complements and physical proof. Different portions of the sacred classics were later forgeries of the eastern Han and Jin dynasties, as evidenced by Han scholarship. The main conclusion from Han learning is that the "Song learning" betrayed the true teachings of Confucius, culminating in decadence, individualism, and factionalism.

To revive classical Confucianism and to some extent, counterbalance Neo-Confucianism, the evidential scholars employed an array of what is now considered scientific approaches ranging from phonology, philology, etymology, paleography, archaeology, epigraphy, and astronomy. The evidential scholars who had no interest in pursuing a political career were able to adhere to purely scientific techniques in their academic endeavors, but the Neo-Confucians viewed *gewuzhizhi* as ultimately serving moral judgment. As early as Needham, it was recognized that the Qing's evidential scholars, in conducting evidential research on classical texts, developed a meticulous procedure and a universe of sophisticated methods that were scientific in nature. The key difference between evidential and Neo-Confucian Dao learning is that the latter had a "preoccupation with human affairs that prevented the Neo-Confucian doctrine of the investigation of things from developing natural science" in China (Chan, 1957). In Hu Shih's evaluation, the revival of evidential learning during the seventeenth and nineteenth centuries "succeeded in leaving to posterity a scientific tradition of dispassionate and disciplined inquiry, of rigorous evidential thinking and investigation, of boldness in doubt and hypotheses coupled with meticulous care in seeking verification" (Hu, 1971).

The *shengyuan* quota as the basis of the *keju* system was introduced in the fifteenth century at the provincial level and was assigned at county level by the mid-seventeenth century. The *shengyuan* quota reflects the prevalence of abecedarian learning of Confucian classics with Zhu Xi's exegesis as the state orthodox. Although there was a post-Taiping revision in 1873 to restore Confucian learning to the war-stricken areas as part of the rehabilitation strategy, the county level quota distribution was quite stable during the Qing dynasty. Since the exceptionally good ones out of the *shengyuan* quota pool were advanced to the officialdom and the rest became gentrymen, the *shengyuan* quota represents both the excellence of scholarly mastery of the Confucian canon and the degree of compliance to Neo-Confucian moral codes and ethics.[5]

Precisely because of the integration of Confucian moral codes and learning in the *keju* oriented education, the Confucian literati was seen as a symbol of backwardness and decadence, in the eyes of reformers. The confrontation between the conservative Confucians and reformers who upheld western philosophy was concluded by the triumph of the latter at the time of the New Culture Movement in 1923. This was a long struggle incepted since Tongzhi Restoration. The grand debate of the New Culture Movement was centered on Confucianism and Science, or more precisely 'Metaphysics and Science' where China's finest thinkers and scientists joined the debate. A consensus accusing Confucianism (regardless of its ethics, learning, or philosophy) as the hinderance of China's failure of modernization emerged.

The abolition of the imperial examination in 1905 gave the gentry class a strong incentive to pursue western learning as job security and social status no longer existed. The gentry began to aspire to the "new schooling" and vehemently reject Confucian learning, evidenced by their investments and personal involvement in founding the new-style schooling, foreign language, and specialized technical training (Wang, 1997). Under the influence of the new-style schooling, the initial transformation of the gentry shifted from the product of the imperial examination into a group actively promoting the new-style schooling (Li, 1980). In fact, before the abolition of the imperial examination, the Qing court considered the outlet for the gentry. Indeed, when Empress Dowager Cixi consulted on the possible alternative education for the gentry, Zhang Zhidong offered teaching opportunities for *shengyuan* aged over 30 at primary schools (Taga, 1972). The Western-style schools were also mandated to admit young *shengyuan* to smooth the transition of the education system.[6] In the early stage of new-style education, a significant portion of gentry obtained "new qualifications" through new-style education and thus had dual identities. By 1915, the number of new-style schools had skyrocketed to 129,739 from merely 222 in 1902, and at the same time, there were 4,294,267 students compared to 6,804 in 1902 (Shu, 1981). It is worth mentioning that under the influence of the new-style school education, the training of various STEM talents received particular attention. By the

[5] Since Zhu Xi's exegesis is mandatorily imposed in the imperial examinations, and Zhu Xi is the founder of Dao learning as the core of Song Neo-Confucianism, the *keju* titles at lower ranks obviously reflects the influence of Neo-Confucian ethics.

[6] *On the outlets of Shengyuan after the abolition of imperial exams* (*tingzhi keju hou zhi shengyuan chulu*), Shenbao. September 7, 1902.

1940s, engineering professionals trained in the past three decades had become the backbone of China's new industrial and mining enterprises, scientific research, and educational institutions (Li, 2018).

According to thinkers such as Immanuel Kant in his landmark essay "What is Enlightenment? ", the emergence of Newtonian science and contemporary democracy were ensured by independent, autonomous, and critical thought that is free from persecution by traditional authorities such as religious groups. Contrarily, the stereotypical image of Confucianism is that it propagates a strict, rigid, and stratified hierarchy based on the obedience core of the filial order and, allegorically, the political rulership's absolute authority. The essential crux of the idea about how Confucianism hampered modernity is this conservativeness or backwardness descriptor. However, as Rousseau noted, independent critical thinking cannot exist without a specific type of authoritative ideal as freedom does not entail being unconstrained by the law. Indeed, in Kant's terms, it was the the "Categorical Imperative" as the authority of individual principle of morality that is practically rational that replaced traditional authorities in the Enlightenment.

Likewise, the Confucian didactic approach never lectures students at length on a subject, just like Confucius did. Instead, as Confucius remarked in the *Analects* that learning without thinking is dangerous, and the Confucian learning traditions encouraged students to develop their own interpretations or answers to the canons independently. As such, 'Confucianism' and 'Science', similar to 'tradition' versus 'modernity' elsewhere in the world, do not always indicate an exclusive or antagonistic relationship. In fact, we contend that on the one hand, the Song learning stretched out on the conservative part of the Neo-Confucian ethics, the Han learning or evidential learning, on the other hand, emphasized the independent thinking legacy of the teaching of Confucius. Thus, though the Confucian Renaissance's prescription of Confucianism as the source of modernity may oversimplify their genuine relationship, the Weberian view which based on the *prima facie* praxis of Confucianism that ascribes Confucianism as the scapegoat for the failure of modernity to originate from China may also be mistaken.

3. Data

Our sample consists of cross-sectional data from 262 Chinese prefectures, excluding frontier regions with major data gaps. For each sampled prefecture, we have three measures of its STEM talents, the number of *shengyuan* quota, new-style schooling (number of schools and number of students), the number of *jinshi* as a proxy of historical human capital, the number of prestigious evidential scholars, and three measures representing the strength of Neo-Confucian culture, among other prefecture-level characteristics.

3.1. STEM talents

Literature demonstrates that scientists are the most important factor, if not the sole factor, in the production of scientific research. We estimate scientific achievements by the number of eminent scholars and other scientific capabilities.[7] We use the number of all scientific talents in constructing the data, without giving special weight to "star" scientists.[8] The three measures of the STEM talent employed here are as follows.

The first is a compilation of China's scientists and engineers in the 1930s, which is collected from the *Who's Who of Chinese Engineers*. This is an exhaustive survey conducted jointly by the Department of Economic Affairs and the Natural Resources Commission. It consists of all graduates from post-secondary educational institutions with specializations in STEM majors, as well as those who had obtained their degrees elsewhere but were established professionals in STEM fields. The eventual publication of the *Who's Who* that covered individuals surveyed by this committee took place in 1941 and featured 15,264 people. It should be noted, however, that although the survey was formally published in 1941, the data reflects the stock of STEM talent that existed in the mid-1930s, since the questionnaires were dispatched and collected from 1933 to 1936. The full-scale outbreak of the Sino-Japanese War in 1937 prohibited any nationwide surveys from taking place after that year. The 1941 *Who's Who*, therefore, is the only exclusive survey of STEM talent in the Republican period and can serve as a cross-sectional variable of Chinese STEM talent in the mid-1930s. We digitized the *Who's Who of Chinese Engineers* and encoded the coordinate information according to the detailed addresses of each individual. The numbers of engineers were aggregated and logged at the prefecture level to reflect the strength of STEM talent in the 1930s at this level, denoted by ln (*Chinese engineers-1930s*).

The second is the number of individual scientists in Chinese Academy of Science (CAS) who had accomplished significant academic achievements as of 1988, as reported in the 1990 edition of the *CAS Distinguished Researchers*. The CAS is frequently viewed as emblematic of those who formed the backbone of China's scientific and innovation system. The CAS is a merit-based academic society and a system of higher education that employs much of China's best scientific and engineering talent. The CAS is home to 80% of China's large-scale science facilities, including the eye-catching Beijing Electron Positron Collider (BEPCII), the Experimental Advanced Superconducting Tokomak (EAST), and the 500-meter Aperture Spherical Telescope (FAST), among others. In 1989, the CAS conducted an extensive survey of its full and associate professors who had made significant contributions in science, such as recipients of provincial-level (or higher) science awards. The survey purposely downplayed these recipients' administrative titles,

[7] The existing literature confirms that overall human capital embodied in the science talents plays a substantial and persistent role in scientific innovations (e.g., Waldinger, 2010, 2016; Borjas and Doran, 2012; Hvide and Jones, 2018).

[8] One may argue that star scientists played more eminent roles in promoting the research frontier. However, Helmers and Overman (2016) suggest that the productivity of individual scientists should not be exaggerated through examining the impact of the Diamond Light Source synchrotron. On the role of superstar scientists, although it is debatable whether the productivity of the coauthors of these superstars suffered losses when the superstars left their positions (Waldinger, 2012 vs. Azoulay, Zivin, and Wang, 2010), the literature finds that the premature deaths of some eminent scientists may have even benefited the field as a whole by pushing the research frontier forward.

to ensure that the selection principle was purely scientific and merit-based. The project listed 4,500 CAS professors and their short biographies are contained in the publication *CAS Distinguished Researchers*. Individual professors' names, research fields, affiliations, professional titles, places of birth, and their main scientific contributions are reported in this survey. This survey complements the *Who's Who of Chinese Engineers* published in 1941, since the political regime change in 1949 was the single most important event in terms of institutional change in China after World War II. Similarly, we digitized the *CAS Distinguished Researchers*, and aggregated them to the prefecture level in logged form as our second measure of STEM talents, denoted as ln (*CAS scientists-1980s*).

Since the majority of CAS research institutes are located in Beijing, it is logical to suspect that southern China may have been underrepresented in its staffing. As a further check on our data, our third measure is the number of STEM professors in 1987, which is sourced from the *Who's Who of Professors in Chinese Universities*, published in 1988. This publication is the result of a nationwide survey of all full professors who obtained their professorship before October 31, 1987, in Chinese higher education institutions, excluding emeritus professors and CAS staff. These scientists' short bios include their birth dates, home towns, main academic contributions, and academic affiliations, such as editorships of scholarly journals. This *Who's Who* includes 17,087 professors. We compiled all professors' information and excluded 4,125 professors in the arts, social sciences, and humanities (e.g., law, education, economics, literature, history, politics, sociology, and philosophy) and retained 12,962 professors in disciplines in the sciences (e.g., physics, chemistry, astronomy, geography, meteorology, biology, mathematics), engineering (mechanics, machinery manufacturing, electronics, telecommunications, architecture, hydraulic engineering, aerospace technology, weapons manufacturing), agriculture, and medicine. Finally, we aggregated the data to the prefecture level in logged form as our third measurement of STEM talents, denoted by ln (*STEM professors-1980s*).

3.2. *The* shengyuan *quota*

Our primary explanatory variable is the *shengyuan* quota, which is the government-mandated number of individuals who had passed the entry-level imperial exam, pertinent to a locality. Specifically, those who had passed entry-level examination in a prefectural capital were referred to "*shengyuan*" as the members of the lowest tier of the gentry, whereas those who advanced and passed the triennial provincial qualification examination held in the provincial capital were referred to as "*juren*". The highest-level exams were administered at the national level and held in the capital of the empire. Those who passed the final level of the imperial exams were awarded "*jinshi*".

As an institutional tool to limit and regulate the authority of elites (Elman, 2000), the quota system was first implemented in 1425 at the provincial level to balance the spatial distribution of candidates for higher level imperial examinations. In 1436, the central government began to appoint government officials to each prefecture for selecting provincial exam candidates (Li, 1989). The prefecture examination quotas were assigned during 1644-1724 where the quota at the county level was set at 20 but was drastically reduced to between 4 and 5 by 1658 and rose to between 7 and 8 by 1670. By 1724 or the second year of Emperor Yongzheng's reign, a major revision to the quota took place where the quota for counties with the most advanced levels of learning was set at 16. The average quota during the 1724 revision was 13 per county and increased to 19 in the 1873 revision as a response to the impacts of the Taiping Rebellion. Despite the fact that the determination and modifications of the quotas were ostensibly based on the popularity of traditional learning at the county level, the observed variances between county quotas were fairly minor. In fact, in the 1724 imperial edict on quota revision, the emperor's justification was based on the individual student's perception of the exam's fairness.[9]

We employ the quota after the Taiping Rebellion, because the county-level quota for the entry-level civil exam remained quite stable throughout the Qing with the exception of adjustments following the Taiping Rebellion. Specifically, we aggregate the number of quotas at prefecture level based on the number of quotas in each county attached to that prefecture and quotas allocated at the prefecture-level but shared among counties in logged form as our measure of prefectural quota, denoted by. ln (*Quota*). The county-level quota statistics were sourced from Kun (1899).

3.3. *New-style schooling*

Based on the 1909 education survey, the strength of new-style schooling at the prefecture level is measured by the logged number of new-style schools, or ln (*School*). The national education authority conducted and compiled the education survey three times between 1907 and 1909, following the 1904 educational reform. The 1909 survey was the most extensive and accurate of the three. It recorded the number of new-style schools, including elementary, secondary, part-time, kindergartens, high schools, and women's schools in every county. Schools jointly operated by multiple counties within a prefecture are also included. In the robustness check, we use the logged number of students in new-style schools, denoted by ln (*Student*), as our alternative measure of new-style schooling.

3.4. *Human capital*

Following Chen, Kung and Ma (2020), we use the logged numbers of *jinshi* (denoted by ln *Jinshi*), as our proxy for historical human capital. The data for Jinshi is available from the China Biographical Database (CBDB), jointly maintained by Harvard University,

[9] According to the 1724 decree, the increased modification of the quota was necessitated by the fact that competition in the imperial tests was so fierce that many candidates repeatedly failed, some until they reached old age.

Academia Sinica, and Peking University. Specifically, according to the index year of the Jinshi, the numbers of Jinshi awarded after 1425 are counted in order to time lag the quota system which was formally established in 1425.

As we argue throughout the paper, evidential scholarship contributed to the rise of modern science in China as its learning tradition employed a variety of methods that were scientific in nature. By the late nineteenth century, evidential learning had gained solid recognition and reformers' endorsement, as shown in the categorization of Confucian learning by Zeng (1869). In particular, in the four dimensions of Confucian scholarship, i.e., yili (moral and philosophical principles), kaoju (evidential learning), cizhang (poetry and prose), and jingji (statecraft), evidential learning was second in significance only to Song learning (Zeng, 1869). The methodology and spirit embodied in evidential studies were in line with modern science. The most prominent bases of the evidential scholars, such as Suzhou, Yangzhou, and Shaoxing, nurtured a handful of renowned scientists in the succeeding eras. Our primary data source for these evidential scholars is *The Directory of Evidential Scholars in the Qing Dynasty* (Guochao Zhushu Zhujia Xingminglu) as an appendix to the *Q&A Bibliography* (Shumu Wenda), which was compiled by Zhang Zhidong (1875) in an effort to provide a comprehensive list of Confucian classics, with a focus on evidential learning. A total of 203 evidential scholars with their birthplaces are given. Additional celebrated evidential scholars were gathered from local gazetteers to supplement, bringing the total number of evidential scholars to 302. To represent the impact of evidential learning, the number of evidential scholars is aggregated at the prefecture level and denoted by ln (*Evidential scholar*).

3.5. Neo-Confucian culture

The central premise of this study is that the cultural features of Confucianism, exemplified by Neo-Confucianism ethics, did not contribute to the development of science in China. Unlike other religions (e.g., Christianity or Buddhism), whose strength can be measured by their religious establishments, such as their missions or monasteries, the degree of adherence to Neo-Confucian principles was not strongly associated with typical religious venues such as Confucian temples. Recognize that although the Confucian literati's moral faith in Confucian ethics and their sincerity in the sacrificial ceremonies to Confucius and the sage kings cannot be underestimated, Neo-Confucianism's core values of "introspection" (neixing), emphasized by the leading Neo-Confucian philosophers such as Zhu Xi and the Cheng brothers, moved away from the Five Confucian Classics towards an inward improvement of morality that was governed not by social conventions or rituals but by inner sources of morality. Recent literature has explored various sources of statistics as proxies for Neo-Confucian values. Following Chen, Ma and Sinclair (2021), Kung and Ma (2014), and Zhou (2021), we employ the following three variables to characterize the strength of Neo-Confucianism ethics.

Our first measure of Neo-Confucian values is the logged number of genealogy books of the Confucian clans in a prefecture in 1898, denoted by ln(*Genealogy*). These genealogies were written records of the male family members of a Confucian patrilineal clan. The genealogy books also included family rules that were embodied in inherited Confucian teachings that stipulated the code of conduct for members. The ultimate goal of these books was to promote clan cohesion and inter-clan communication (Chen, Ma, and Sinclair, 2021). The connection between a clan's genealogy and the legitimacy of the crown through the metaphor between the filial piety within families and allegiance to the emperor was elucidated by the great Neo-Confucian philosophers, such as Zhang Zai (1020-1077) and Cheng Yi (1033-1107). Furthermore, Neo-Confucians attributed moral degradation to the loss of the original truth as a result of the disorder or mismanagement of commoners' genealogies, particularly because the mixing of main and branch lineages did not rigorously adhere to the standards established in Antiquity. Separating and privileging the main lineages (da zong) from their agnate lines was considered a solution for the return to the truth (and harmonious societal order). In doing so, Neo-Confucians elevated genealogy, as the organization of kin into patrilineal descent systems to the pinnacle of ideological issues. As a consequence, in places heavily influenced by Neo-Confucian teachings, more genealogical books were systematically compiled and preserved. We use dataset of genealogy books from Chen, Ma, and Sinclair (2021) who collected from the Shanghai Library's 2009 edition of the *Comprehensive Catalogue on Chinese Genealogy* (Zhongguo Jiapu Zongmu). This valuable survey comprises 52,306 clans in China, comprising over 700 surnames throughout 283 prefectures. We used the number of genealogies in a prefecture before 1898, the year of the promulgation of the "decree requesting that all traditional Confucian academies be converted to Western-style schools at all administrative levels." By doing so, we avoid a reverse causality between the new-style schooling and the strength of Confucianism.

Our second measure is the number of Confucian academies in logged form, or ln (*Confucian academy*). The Confucian academy which began to flourish in the twelfth century served as the main venue for the spreading of Neo-Confucian culture. Through the propagation of these academies' own interpretation of Confucian values to their adult students, the Confucian academies promoted Neo-Confucian ethics under the auspices of Song learning (Lee, Glomb, and Gehlmann, 2020). The four books and five classics constitute the primary curriculum in the academies. Neo-Confucianism expanded its influence in academic and social fields through the academies. The data source on the academies comes from Ji (1996), who recorded the names of the academies, their years of establishment, locations, founders, and pertinent information in detail. We construct the numbers of academies at the prefecture level between 1425 and 1898 as the second measure of Neo-Confucian values.

Our last measure is the number of chaste women (logged) officially elected by the imperial courts, denoted by ln (*Chaste women*). One of the core Neo-Confucian moral ethics embedded in the notion of introspection was to "uphold celestial justice and annihilate human desire," which was proposed by Zhu Xi, the greatest Neo-Confucian philosopher. Such moral ethics discouraged a widow from remarrying and in most places where a widow was allowed to remarry, she was stripped of the privileges she once had with her former husband's family, such as owning property and having her name included in the family genealogy. In addition to the introspection that discourages undue human desire, other Neo-Confucian philosophers, notably Zhou Dunyi and Cheng Yi, invoked a gender hierarchy into the order of the cosmos where the wife is subservient to her husband, just as the minister is faithful to his master. For a widow, sexual fidelity even after the death of her husband was considered an essential virtue as it served as a metaphor

for loyalty to the throne.[10] This chastity had been recognized and awarded by commemorating the widow's celibacy or her suicide in the face of a sexual assault. Celebrated acts of chastity were recorded and awarded imperial testimonials of merit (jingbiao) and, by the late Ming dynasty, this had been formalized and overseen by the imperial court and the system was inherited by the Qing dynasty (Theiss, 2004). The distribution of chastity records can nevertheless represent the degree of Neo-Confucian influence across Chinese localities, regardless of whether the formation was top-down or bottom-up. Kung and Ma (2014) claim that chastity was a reliable measure of Confucian norms. Our data on chastity is sourced from the official dynastic histories, including *mingshi* and *qingshigao*. In each of these official histories, a separate chapter entitled "*lienü zhuan*" reports the celebrated exemplary women who died to protect their chastity. Specifically, we excluded the chaste women who were awarded the title of chaste woman before 1425.

3.6. Control variables

It is necessary to control for a number of covariates that likely affected the dependent variable and independent variable. We classified these control variables into five categories.

The first category is a vector of economic control variables, including the population, the number of industrial firms, and the land tax per capita. In the absence of reliable GDP figures, the population is a prior proxy for measures of historical economic prosperity (Acemoglu, et al, 2001; Bairoch, 1988). We control for the logged population in 1910 (ln *Populationa*) when the dependent variable is STEM talents because most STEM talents in our study were born in the late Qing and Republican era. When the dependent variable is new-style schooling, we control for the logged population in 1880 (ln *Populationb*), the last year prior to 1909 for which prefectural population data are available. These data were obtained from Cao (2001), who provides reliable population estimates at the prefecture-level. Moreover, since the Opium War had opened China to Westerners, modern mechanized industries began to boom in many of its cities. The development of modern industries provided additional incentives and an atmosphere for STEM talents and Western learning within a locality. Chang (1987, 1988a, 1988b, 1989) provides exhaustive surveys of China's modern industries at the firm level for the categories of foreign-owned, state-owned, government-supervised and merchant-managed, and private firms.[11] We aggregate the four types of firms Chang compiled as the number of modern industrial firms established before 1916 as a control variable, or ln (*Firmsa*), when the dependent variable is STEM talent. We control for the logged industrial firms in 1896, denoted by ln (*Firmsb*), in regressions where the dependent variable is new-style schooling. More importantly, the *land tax per capita* should be controlled in our study, because this tax can also reflect local economic conditions. Land tax revenues reflect the development of the local agriculture sector in a traditional society and were the mainstay of government finance in imperial China. We obtained the data on the land tax per capita for 1820 from Liang (1981), which was the only available land tax data for the Qing dynasty and was also used in previous studies, such as those of Chen, Wang, and Yan (2022) and Bai and Jia (2016).

The second category is a vector representing Western influences, including the number of Christian missions in 1920, dummy of treaty port, and dummy of coastal prefecture, denoted by *Protestant missionaries*, *treaty port*, and *Coastal*, respectively. The inauguration and early development of Western learning and the sciences were heavily influenced by Christian missions during the Qing dynasty. Christian missionaries attempted to transplant the entirety of Protestantism into China, including Western science, education, and culture (Chen, Wang, and Yan, 2022). Moreover, previous literature suggests that the treaty ports were an important factor that influenced scientific communication in the late Qing. One unintended consequence of China's opening up to international trade was modernization (Nield, 2015). The opening of the treaty ports promoted the diffusion of modern scientific thought throughout China (Zhang, Feng, and Bai, 2021). Moreover, prefectures located on the coast were likely early beneficiaries of Western knowledge (Chen, Kung, and Ma, 2020). The data on the Protestant missionaries were provided by Stauffer (1922), who surveyed the distribution of all Protestants and their related activities across Chinese counties in 1920. This one-of-a-kind cross-sectional data was widely used in economic history studies such as Chen, Ma, and Sinclair (2021), Bai and Kung (2015), and Chen, Wang, and Yan (2022). The treaty port data were sourced from Nield (2015), and the coastal prefecture data is collected from the China Historical Geographic Information System (CHGIS, 2016).

The third category contains several geographic factors that may be correlated with the density and distribution of STEM talents and schools, including the land area (ln *land area*), the distance to the nearest river (ln *river dist*), and whether located in northern China[12] (*north*). In particular, the materials needed for printing books were transported along major navigable river tributaries (Chen, Kung, and Ma, 2020). The data on geography were all obtained from CHGIS (2016).

The fourth category is a set of local governance factors of a prefecture, which were obtained by compiling a data set containing the following measures: *chong* (traffic frequency), *fan* (important in administrative businesses), *pi* (late payment of taxes and grain),

[10] Sun Qifeng (1584–1675), a leading Neo-Confucian, remarked that "to die to preserve fidelity is more heroic than to live to preserve it……The relationships that bind a ruler to his country, a minister to his ruler, a son to his father, and a wife to her husband are designated by Heaven and rooted in human feeling….. For a woman who has never seen her fiancé, dying for him is comparable to the deed of a man who dies for his ruler without ever having served him. This is most heroic!" (Sun, 1936)

[11] Foreign investors began to establish modern *firms* in China in 1841, followed by Chinese private investors in 1848, and the state-owned industrial sector focused on the production of weapons at the beginning of 1861 as a response to the Taiping Rebellion. Government-supervised and merchant-managed firms flourished from 1870 to the 1890s, as an integrated part of the Self-Strengthening Program, and then faded out in the 1890s. Chang Yu-fa applied the following criteria in selecting modern firms: they must have been corporate organizations, have had registered capital of more than 10,000 silver taels or yuan, have used machinery and automotive power, employ over 30 workers, and have had an annual turnover of more than 50,000 yuan.

[12] latitude>26.9

Table 1
Summary Statistics for the Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
ln(Chinese engineers-1930s)	262	2.58	1.744	0	7.563
ln(CAS scientists-1980s)	262	1.613	1.431	0	5.613
ln(STEM professors-1980s)	262	2.551	1.55	0	6.548
ln(Quota)	262	4.441	0.891	0.693	6.047
Smallrivers/River lenght	262	0.886	0.436	0	3.163
Δln(PScholar)	262	0.377	0.727	-1.872	2.303
ln(School)	262	4.33	1.361	1.386	6.407
ln(jinshi)	262	3.87	1.746	0	7.242
ln(Evidential scholar)	262	0.351	0.7	0	3.611
ln(Genealogy)	262	2.204	1.82	0	7.566
ln(Academy)	262	2.842	1.038	0	5.609
ln(Chaste Women)	262	0.978	0.961	0	3.638
ln(Populationa)	262	6.967	0.950	3.807	8.933
ln(Populationb)	262	6.792	0.974	3.584	8.832
ln(Firmsa)	262	0.607	1.051	0	6.08
ln(Firmsb)	262	0.18	0.544	0	4.06
Land tax per capita	262	0.078	0.068	0.001	0.316
Protestant missionaries	262	41.111	70.591	0	558
Coastal	262	0.134	0.341	0	1
Treaty port	262	0.115	0.319	0	1
ln(Land area)	262	9.336	0.77	7.147	12.166
ln(River dist)	262	5.176	1.148	1.5	7.031
North	262	0.729	0.445	0	1
pcapital	262	0.069	0.253	0	1
Chong	262	0.615	0.488	0	1
Fan	262	0.76	0.428	0	1
Pi	262	0.267	0.443	0	1
Nan	262	0.676	0.469	0	1
Newspaper	262	4.779	29.197	0	410

and *nan* (high in criminal incidents). The composition of a locality's chong, fan, pi, and nan determined how challenging it was to administer, and was also a significant consideration for selecting local officials. For example, when a region is labeled "chong," the government would dispatch a more competent official to oversee that region (Chen, Peng, and Zhu, 2017). These designations were available for each prefecture and their codes are based on Zhao (1928). In addition, we include a dummy variable indicating whether the prefecture is the provincial capital (*pcapital*).

Last but not least, the newspaper as a media may have affected the dissemination of science. We, therefore, controlled for the number of newspaper (logged) in 1911 to measure the effect of media in spreading knowledge. The data of newspaper is sourced from Bai and Jia (2016). The summary statistics for the variables are given in Table 1. The details of variable definitions and data sources are provided in the Appendix. The data and the replication files can be accessed online at Dong and Zhang (2023).

4. Model and Empirical Results

Our analysis consists of two steps. In the first step, we regress late period outcomes such as modern STEM talent and new-style school in the long run against *shengyuan* quota. In addition to the OLS estimations, the two-stage least squares (2SLS) approach is used to validate the causal relationship between the quota and the late period outcomes. In the second step, we investigate the mechanism by which the quota influenced STEM talent and new-style school. Specifically, we empirically examine the following three hypotheses: (1) Quota explains historical human capital, measured by the number of *Jinshi* and evidential scholar; (2) Quota explains the strength of Neo-Confucian ethics, measured by the density of genealogy books, chastity, and Confucian academy; (3) The rise of modern science in China can be explained by the human capital but not its culture. We conclude with a robustness check.

4.1. Quota, STEM talent, and New-style schooling

4.1.1. Quota and STEM talent

We begin with our baseline estimation for the effects of quota on STEM talent in the following specification:

$$STEM_i = \alpha_1 + \beta_1 Quota_i + \gamma_1 \mathbf{Z}_{1i} + \theta_p + \varepsilon_{1i} \quad (1)$$

where i indexes the prefectures; STEM is the natural logarithm of our measures for STEM talents, including ln (*Chinese engineers-1930s*), ln (*CAS scientists-1980s*), and ln (*STEM professors-1980s*); *Quota* is the natural logarithm of the *shengyuan* quota; $\boldsymbol{Z_1}$ is a vector of prefecture-level characteristics, including population in 1910, industrial firms in 1916, land tax per capita, number of Christian missionaries, treaty port dummy, coastal dummy, land area, distance to the nearest river, northern China dummy, difficulty of local governance captured by chong, fan, pi, nan, provincial capital dummy, and newspaper in 1911;θ_p represents the provincial dummies; and ε is the error term.

Table 2
Quota and STEM Talents: OLS Estimates

	ln(Chinese engineers-1930s) (1)	ln(CAS scientists-1980s) (2)	ln(STEM professors-1980s) (3)	ln(Chinese engineers-1930s) (4)	ln(CAS scientists-1980s) (5)	ln(STEM professors-1980s) (6)
ln(Quota)	1.207***	0.924***	1.163***	0.226**	0.190**	0.351***
	(0.112)	(0.0967)	(0.100)	(0.110)	(0.0963)	(0.104)
ln(Populationa)				0.716***	0.647***	0.627***
				(0.113)	(0.0974)	(0.110)
ln(Firmsa)				0.180***	0.293***	0.338***
				(0.0666)	(0.0689)	(0.0724)
Land tax				2.231**	-0.662	0.582
				(1.096)	(1.167)	(0.890)
Protestant missionaries				0.0002	0.0009	0.0009
				(0.0009)	(0.001)	(0.001)
Coastal				0.469**	0.181	0.339*
				(0.212)	(0.189)	(0.201)
Treaty port				0.0644	0.196	0.00435
				(0.169)	(0.136)	(0.150)
ln(Land area)				-0.126	-0.283***	-0.204**
				(0.0902)	(0.0866)	(0.0875)
ln(River dist)				-0.114	0.0287	0.0173
				(0.0733)	(0.0677)	(0.0720)
North				-0.0789	0.329*	0.0513
				(0.320)	(0.187)	(0.297)
pcapital				0.723***	0.206	0.345
				(0.222)	(0.241)	(0.225)
Chong				0.229**	0.245**	0.197*
				(0.113)	(0.113)	(0.113)
Fan				0.0372	0.234	0.0985
				(0.158)	(0.144)	(0.145)
Pi				0.259**	-0.0307	-0.000323
				(0.115)	(0.119)	(0.118)
Nan				0.104	0.220*	0.186
				(0.134)	(0.124)	(0.126)
Newspaper				-0.003**	-0.002*	-0.003***
				(0.0015)	(0.0012)	(0.0011)
Province FE	No	No	No	Yes	Yes	Yes
Observations	262	262	262	262	262	262
R-squared	0.413	0.378	0.494	0.815	0.756	0.783

Notes: Constant terms are omitted from the report and robust standard errors in parentheses.
***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2 shows the baseline results for specification (1). Before controlling for other factors, we only regress three measures of STEM talents on quota in columns (1)-(3). In all cases, the quota is shown to have had highly significant (at the 1% level) and positive effects on the three measures of STEM talents. To deal with the possible bias from the omitted variables, we include the controls aforementioned and provincial fixed effect into our regressions in column (4)-(6) to rule out spurious regressions. The key results remain significant (at the 1% level). The magnitude of the coefficient of *ln*(*Quota*) indicates that doubling the number of quota for a prefecture would are correlated with the number of the stock of Chinese engineers in the 1930s, CAS researchers in the 1980s, and full professors of STEM disciplines in the 1980s increased by 22.6% (column 4), 19% (column 5), and 35.1% (column 6), respectively. The estimated effect is smaller than that of the regressions no controlled for any other variables (column 1-3), suggesting that the quota effect may have been overestimated if we had not adjusted for the missing variables. However, these results all manifest the prominent role of *shengyuan* quota in explaining the rise of the STEM talents.

Although we already controlled for many potential confounders, there may still have been omitted variables, such as political networks, that was associated with quota. The role of such omitted variables was likely to become more important in subsequent reforms in education and hence increased the stock of STEM talents. To deal with these concerns, we employed the 2SLS approach. Conceptually, a valid instrument should be related to the quota but does not affect STEM talents directly via channels other than the quota variable.

Our choices of IVs for the number of quotas follow Bai and Jia (2016). Specifically, the first IV is the number of small rivers excluding major rivers[13] and normalized by the total length of rivers, i.e. *small rivers / River lenght;* the second IV is first difference of

[13] Major rivers may be correlated with economic factors, and then affect STEM talents through economic factors, which does not meet the characteristics of instrumental variables, thus it is excluded. Although small rivers may be a result of terrain ruggedness which is commonly believed to directly affect socioeconomic development negatively and therefore poses a threat to the IV's exogeneity, the anecdotes of China do not lend support to this postulation. For instance, during the Spring and Autumn Period (771-483BC), the Kingdom of Chu as a dominant hegemon, which

Table 3
Quota and STEM Talents: 2SLS Estimates

	ln(Chinese engineers-1930s) (1)	ln(CAS scientists-1980s) (2)	ln(STEM professors-1980s) (3)	ln(Chinese engineers-1930s) (4)	ln(CAS scientists-1980s) (5)	ln(STEM professors-1980s) (6)
ln(Quota)	1.981***	1.864***	2.182***	0.420	0.679**	1.601***
	(0.317)	(0.295)	(0.319)	(0.342)	(0.330)	(0.479)
			First Stage			
Smallrivers/River lenght	0.346*	0.346*	0.346*	0.164**	0.164**	0.164**
	(0.185)	(0.185)	(0.185)	(0.082)	(0.082)	(0.082)
Δln(PScholar)	0.283***	0.283***	0.283***	0.182***	0.182***	0.182***
	(0.069)	(0.069)	(0.069)	(0.042)	(0.042)	(0.042)
F-statistics	11.282	11.282	11.282	10.902	10.902	10.902
P-value of the over-id test	0.508	0.964	0.343	0.176	0.815	0.364
Baseline controls	No	No	No	Yes	Yes	Yes
Province FE	No	No	No	Yes	Yes	Yes
Observations	262	262	262	262	262	262
R-squared	0.243	0.574	0.115	0.813	0.731	0.646

Notes: The baseline controls are the same as the control variables in Table 2.
Constant terms are omitted from the report and robust standard errors in parentheses.
***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

exam performance in two sub-periods of similar length (1399-1425 versus 1368-1398) to remove time-invariant factors, denoted by Δln(*PScholar*). The justifications for the choices of the two IVs can be found in Bai and Jia (2016).

We now examine the casual effects of quota on STEM talent in specification (2) and (3) by using the following 2SLS method:

$$STEM_i = \alpha_2 + \beta_2 \hat{Quota}_i + \gamma_2 \mathbf{Z}_{1i} + \theta_p + \varepsilon_{2i} \tag{2}$$

$$\hat{Quota}_i = \alpha_3 + \rho_1 \frac{small\ rivers}{river\ lenght} + \rho_2 \Delta \ln(PScholar)_i + \gamma_3 \mathbf{Z}_{1i} + \theta_p + \varepsilon_{3i} \tag{3}$$

The instrumented results are reported in Table 3. In columns (1)-(3), without controlling for any control variables, the estimated coefficients for the quota remain positive and statistically significant. The F-statistics and over identification statistics reported in the bottom panel of Table 3 indicate that the two IVs are not weak instruments and do not over identify.

In the rest of Table 3 where control variables are in place, we find a positive and statistically significant effects of quota on the stock of CAS researchers in the 1980s (column 5) and full professors of STEM disciplines in the 1980s (column 6). However, the loss of statistical significance of estimated coefficient of quota when the dependent variable is the stock of Chinese engineers in the 1930s as shown in column (4), implies that the ambiguous effect of Confucianism at its wholesale use could be problematic. Indeed, it is plausible that this insignificance result may be driven by the twist of the facilitating role of human capital and the inhibiting role of culture, both of which were governed by the broadly defined Confucianism. In subsection 4.2, we disentangle the two channels that could have countervailed.

4.1.2. Quota and New-style schooling

As shown by the anecdotes in the background section, we argue that the new-style school served as a channel running from the gentry to science. We examine this premise in specification (4).

$$School_i = \alpha_4 + \beta_4 Quota_i + \gamma_4 \mathbf{Z}_{2i} + \theta_p + \varepsilon_{4i} \tag{4}$$

where $School_i$ stands for the new-style schooling measure as the total number of new-style schools in 1909 aggregated at the prefecture level and raised to the natural logarithm. $\boldsymbol{Z_2}$ represents a vector of prefecture-level characteristics, including population in 1880, industrial firms in 1896, and other time-invariant variables used in (1). It can be concluded from the results reported in Table 4 that the quota explains the rise of new-style schools in both OLS and 2SLS settings and the result is robust against the changes of control variables.

We then regress STEM talent against new-style school using the same set of control variables in (1) and the results are reported in Table 5. Observe that all estimations show a significantly (at the 1% level) positive effect of the new-style schooling in determining

corresponds to a vast land covering South Henan, Hubei, Hunan, East Sichuan, and West Anhui provinces of today's China, rich in small rivers, had a productivity higher than other kingdoms and dukedoms. The literature offers several interpretations on the supremacy of the Chu Kingdom such as its wide ranged landforms which yielded compatible farming (Yang et al, 2022) and its hilly and irregular terrain which made invasions by chariots difficult (Fairbank, 1992:54). However, in some other mountainous and small river rich areas in China such as present-day Guizhou and Yunnan provinces, their economic development has been far below national average since ancient times. Thus, the perception that terrain topography directly and unidirectionally affects socioeconomic development is not well supported by the observed facts.

Table 4
Quota and New-style Schools

	Dependent Variable is *ln(School)*						
	OLS						2SLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln(Quota)	0.923***	0.483***	0.858***	0.891***	0.918***	0.483***	0.759**
	(0.102)	(0.171)	(0.112)	(0.117)	(0.114)	(0.182)	(0.384)
ln(Populationb)		0.524***				0.518***	0.385*
		(0.136)				(0.159)	(0.205)
ln(Firmsb)		0.169***				0.199**	0.175*
		(0.0618)				(0.0874)	(0.0895)
Land tax		3.105***				2.789***	2.056
		(0.947)				(1.012)	(1.314)
Protestant missionaries			0.00205**			0.00120	0.00115
			(0.000833)			(0.000774)	(0.000745)
Coastal			0.0958			-0.136	-0.0871
			(0.174)			(0.198)	(0.201)
Treaty port			0.00195			-0.0349	-0.0215
			(0.171)			(0.181)	(0.168)
ln(Land area)				0.0609		-0.00517	-0.0711
				(0.0958)		(0.102)	(0.144)
ln(River dist)				-0.0537		0.0145	0.0244
				(0.0798)		(0.0939)	(0.0892)
North				0.310		0.205	0.259
				(0.260)		(0.234)	(0.237)
pcapital					-0.241	-0.494*	-0.567**
					(0.265)	(0.274)	(0.265)
Chong					0.0961	0.0746	0.0159
					(0.127)	(0.122)	(0.153)
Fan					0.114	0.168	0.0939
					(0.163)	(0.155)	(0.190)
Pi					-0.139	-0.200	-0.218
					(0.160)	(0.158)	(0.149)
Nan					-0.0193	-0.0254	-0.0261
					(0.137)	(0.128)	(0.119)
							First Stage
Smallrivers/River							0.194**
lenght							(0.084)
Δln(PScholar)							0.184***
							(0.042)
F-statistics							11.316
P-value of the over-id test							0.159
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	262	262	262	262	262	262	262
R-squared	0.603	0.653	0.611	0.607	0.608	0.664	0.657

Notes: Constant terms are omitted from the report and robust standard errors in parentheses.
***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 5
New-style Schools and STEM Talents

	ln(Chinese engineers-1930s) (1)	ln(CAS scientists-1980s) (2)	ln(STEM professors-1980s) (3)	ln(Chinese engineers-1930s) (4)	ln(CAS scientists-1980s) (5)	ln(STEM professors-1980s) (6)
ln(School)	0.666***	0.517***	0.612***	0.192***	0.189***	0.215***
	(0.0576)	(0.0487)	(0.0547)	(0.0610)	(0.0585)	(0.0585)
Baseline controls	No	No	No	Yes	Yes	Yes
Province FE	No	No	No	Yes	Yes	Yes
Observations	262	262	262	262	262	262
R-squared	0.294	0.277	0.319	0.821	0.766	0.786

Notes: The baseline controls are the same as the control variables in Table 2.
Constant terms are omitted from the report and robust standard errors in parentheses.
***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 6
Quota and Human Capital

	ln(jinshi)	ln(Evidential scholar) OLS	ln(jinshi)	ln(Evidential scholar) 2SLS
	(1)	(2)	(3)	(4)
lnquota	0.993***	0.179*	2.082***	0.550**
	(0.186)	(0.0936)	(0.431)	(0.247)
			First Stage	
Smallrivers/River lenght			0.194**	0.194**
			(0.084)	(0.084)
Δln(PScholar)			0.184***	0.184***
			(0.042)	(0.042)
F-statistics			11.316	11.316
P-value of the over-id test			0.160	0.142
Baseline controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Observations	262	262	262	262
R-squared	0.835	0.525	0.761	0.470

Notes: The baseline controls are the same as the control variables in Table 4.
Constant terms are omitted from the report and robust standard errors in parentheses.
***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

the STEM talent. Quantitatively, a 10% increase of the number of new-style schools, corresponds to an increase of 1.92%, 1.89%, and 2.15% of the aforementioned three types of STEM talent, respectively. The results reveal a strong and significant effect of new-styling schooling as it prospered in the last decade of Qing's reign and continued to have an impact on modern STEM talent, even after nearly a century.

4.2. Human capital vs. Culture

Since quota can reflect both historical human capital and Neo-Confucian values and the use of quota gives us an ambiguous result and misleading interpretation, we examine their roles separately. To implement, we first examine the impact of quota on history human capital and Neo-Confucian values, followed by an investigation of the causal effects of historical human capital and Neo-Confucian values separately on modern science.

4.2.1. The effects of quota on human capital and Neo-Confucian values

Per discussions earlier, we use the number of *jinshi* and evidential scholar as measures of human capital and learning traditions conducive to science as dependent variables and report the regression results in Table 6. The results indicate a statistically significant and quantitatively strong relationship. In particular, doubling the number of quotas corresponds to an increase of 208.2% (column 3) and 55% (column 4) of *jinshi* and evidential scholars, respectively.

We then conduct a similar exercise on quota's effect on Neo-Confucian values and the results are summarized in Table 7. We consider three variables to proxy Neo-Confucian values, namely the density of genealogy books, number of Confucian academies, and records of chaste women. Similar to the effect of quota on human capital, Table 7 reports a clear-cut result of quota on Neo-Confucian ethics. Specifically, doubling in the number of quotas led to the increases in the number of genealogy books, Confucian academy, and chaste women by 142.3%, 90.3%, and 54.6%. These results are consistent with Becker et al (2016), who find that formal institution can have an effect on cultural values.

Table 8

4.2.2. Human capital and Neo-Confucian values on new-style schooling

In this subsection, we conduct a battery of estimations to examine the role of historical human capital and Neo-Confucian values on new-style schooling. Observe from columns (1) to (3), the number of *jinshi* and evidential scholars had a positive effect on the spread of new-style schools regardless of whether they were individually regressed or served jointly.

By contrast, columns (4) to (7) indicate that Neo-Confucian values were not responsible for the growth of new-style schools, whether it was measured by genealogy books, Confucian academy, or chaste women, evidenced by the complete loss of statistical significance for all estimates of the coefficients. Our results here imply that places that were deeply influenced by Neo-Confucian culture but poor in Confucian learning traditions, was not as swift as other places in the transition from traditional education to western-style schooling when the *keju* was abolished.

4.2.3. The effect of Neo-Confucian values on STEM talents

To rule out other possible effect of Neo-Confucian values on STEM talent, we regress the STEM talent against Neo-Confucian values, controlling for the human capital variables and the baseline covariates. As shown in Table 9, we do not find support for a positive

Table 7
Quota and Neo-Confucian Values

	ln(Genealogy)	ln(Academy)	ln(Chaste Women)	ln(Genealogy)	ln(Academy)	ln(Chaste Women)
		OLS			2SLS	
	(1)	(2)	(3)	(4)	(5)	(6)
lnquota	0.400**	0.621***	0.236***	1.423***	0.903***	0.546*
	(0.182)	(0.141)	(0.076)	(0.458)	(0.263)	(0.329)
				First Stage		
Smallrivers/River lenght				0.194**	0.194**	0.194**
				(0.084)	(0.084)	(0.084)
Δln(PScholar)				0.184***	0.184***	0.184***
				(0.042)	(0.042)	(0.042)
F-statistics				11.316	11.316	11.316
P-value of the over-id test				0.142	0.886	0.416
Baseline controls				Yes	Yes	Yes
Province FE				Yes	Yes	Yes
Observations	262	262	262	262	262	262
R-squared	0.747	0.718	0.627	0.686	0.704	0.607

Notes: The baseline controls are the same as the control variables in Table 4.
Constant terms are omitted from the report and robust standard errors in parentheses.
***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively

Table 8
Human Capital, Neo-Confucian Values, and New-style Schools

	Dependent Variable is *ln(School)*						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln(jinshi)	0.244***		0.215***				
	(0.0712)		(0.0786)				
ln(Evidential scholar)		0.274***	0.154*				
		(0.0865)	(0.0905)				
ln(Genealogy)				-0.0220			-0.021
				(0.0707)			(0.064)
ln(Academy)					-0.009		-0.005
					(0.129)		(0.124)
ln(Chaste Women)						0.065	0.065
						(0.087)	(0.088)
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	262	262	262	262	262	262	262
R-squared	0.659	0.647	0.662	0.665	0.665	0.666	0.666

Notes: The baseline controls are the same as the control variables in Table 4.
Constant terms are omitted from the report and robust standard errors in parentheses.
***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 9
Neo-Confucian Values and STEM Talents

	ln(Chinese engineers-1930s)			ln(CAS scientists-1980s)			ln(STEM professors-1980s)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ln(Genealogy)	0.719			0.520			0.793		
	(0.603)			(0.640)			(0.571)		
ln(Academy)		0.0760			0.0128			0.114	
		(0.0759)			(0.0708)			(0.0772)	
ln(Chaste Women)			0.084			0.025			0.059
			(0.077)			(0.076)			(0.079)
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	262	262	262	262	262	262	262	262	262
R-squared	0.827	0.827	0.827	0.772	0.772	0.772	0.804	0.805	0.803

Notes: The baseline controls include the control variables in Table 2 and human capital variables.

Table 10
Robustness Results: Quota, New-style Students, and STEM Talents

	ln(student)		ln(Chinese engineers-1930s)	ln(CAS scientists-1980s)	ln(STEM professors-1980s)
	OLS	2SLS		OLS	
	(1)	(2)	(3)	(4)	(5)
ln(Quota)	0.459***	0.581*			
	(0.152)	(0.335)			
ln(student)			0.270***	0.248***	0.289***
			(0.0659)	(0.0657)	(0.0624)
Baseline controls	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes
Observations	262	262	262	262	262
R-squared	0.658	0.656	0.826	0.771	0.793

Notes: The baseline controls in column (1) and (2) are the same as the control variables in Table 4, and the baseline controls in column (3)-(7) are the same as the control variables in Table 2.

Table 11
Robustness Results: Human Capital, Neo-Confucian Values, and New-style Students

	Dependent Variable is *ln(Student)*				
	(1)	(2)	(3)	(4)	(5)
ln(jinshi)	0.218***				
	(0.0587)				
ln(Evidential scholar)		0.201**			
		(0.0806)			
ln(Genealogy)			0.0137		
			(0.0606)		
ln(Academy)				-0.0254	
				(0.107)	
ln(Chaste Women)					0.094
					(0.083)
Baseline controls	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes
Observations	262	262	262	262	262
R-squared	0.653	0.637	0.654	0.654	0.656

Notes: The baseline controls include the control variables in Table 4.
Constant terms are omitted from the report and robust standard errors in parentheses.
***,**, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

role of Neo-Confucian values on STEM talent, suggesting that Neo-Confucian ethics had no direct or other indirect promotional effect on the rise of modern science.

In sum, in section 4.2, we provide the evidence that historical human capital explains the growth of STEM talents through new-style schools, while our results do not lend support to the claim that Neo-Confucian values were conducive to the emergence of modern STEM talent.

4.3. Robustness check

In the robustness check, we replace the logged number of new-style schools by the logged total number of new-style students. The results are consistent with the ones obtained by using new-style schools, as reported in Tables 10 and 11. Finally, we re-estimate the effect of human capital and Neo-Confucian values on new-style schooling, but employing new-style student as dependent variable. The results are reported in Table 11. The results confirm all implications drawn from the benchmark model.

Overall, the results from our robustness checks deliver a consistent message: the human capital aspect of Confucianism and the evidential scholarship in late imperial times facilitated the emergence and spreading of modern science in China and the effect is even carried over to contemporary period. The facilitating role of human capital took effect through the provision of new-style schooling, which contributed to the consequent dissemination and popularization of science and technology. In contrast, we are unable to identify a similar impact of Neo-Confucian values on the spread of modern science and technology in China.

5. Conclusion

In this paper, we have examined the relationship between Confucianism and science in China during modern and contemporary times. There is a conflict between the observed fact that China has rapidly developed its science since the late Qing and the Needham paradox as an established understanding of the stagnation of Chinese science and technology in imperial China. Likewise, there is a

clash between the prevalent Fairbankian paradigm and a recent strand of literature asserting that Confucianism played a positive or even proactive role here. To tackle these issues, we distinguish the concepts of Confucian learning, Confucianism as a religion, and Confucian moral ethics.

We find that two notable nuances are highly pertinent to the analysis: the cloaking effect of human capital hidden under the umbrella of Confucianism and the stark sectarian differences in attitudes towards modern science. We then employed appropriate measures of human capital and Confucian culture in a new framework and examined the causal relationship between Confucianism decomposed into historical human capital and Neo-Confucian culture, and modern science measured by STEM talent. Our empirical investigations show clear-cut results, i.e., that historical human capital and evidential learning contributed to the upsurge of the new-style schooling and the consequent rise of STEM talent in China, whereas Neo-Confucian values did not.

Needless to say, the Western impact on China's modernization of its education system is evident. Although the current paper lends support to the internal impetus hypothesis, the interactions between the West and Confucianism in late imperial times warrant future research. In the literature, it remains unclear if Western influence and Confucianism were complementary, substitutive, or simply independent in China's modernization process. The approach and findings in the current paper may be applicable in future studies on such themes.

Data Availability

I have shared the link to data and replication files in the paper and response to the editor letter.

Appendix: The Definitions and Sources of Variables

ln(*Chinese engineers-1930s*): China's scientists and engineers during the 1930s. Taken from *The Who's Who of Chinese Engineers*. ln(*CAS scientists-1980s*): CAS's Researchers by 1988. Taken from *The Who's Who of Distinguished Researchers in CAS*. ln(*STEM professors-1980s*): STEM professors obtained their professorship before 1987. Taken from *The Who's Who of Professors in Chinese Universities*. ln(*Quota*): Quotas of people who had passed the entry-level civil exam. Taken from Kun (1899).

Smallrivers/River length: The number of small rivers normalized by the total length of rivers. Taken from Bai and Jia (2016).

Δln(*PScholar*): The first difference of presented scholars in 1399-1425 and 1368-1398. Taken from Bai and Jia (2016). ln(*School*): New-style schools. Taken from the 1909 education survey. ln(*Student*): New-style students. Taken from the 1909 education survey. ln(*jinshi*): jinshi after 1425. Taken from CBDB. ln(*Evidential scholar*): Evidential scholars in the Qing dynasty. Taken from *The Directory of Evidential Scholars in the Qing Dynasty*. ln(*Genealogy*): Genealogy of the Confucian clans in 1898. Taken from Chen, Ma, and Sinclair (2021). ln(*Academy*): Confucian academies. Taken from Ji (1996). ln(*Chaste Women*): Chaste women officially elected by the imperial courts. Taken from *Mingshi and Qingshigao*. ln(*Populationa*): population in 1910. Taken from Cao (2001). ln(*Populationb*): population in 1880. Taken from Cao (2001). ln(*Firmsa*): Industrial firms in 1916. Taken from Chang (1987, 1988, 1989). ln(*Firmsb*): Industrial firms in 1896. Taken from Chang (1987, 1988, 1989).

Land tax per capita: Land tax per capita in 1820. Taken from Liang (1981).

Protestant missionaries: Protestant missionaries in 1920. Taken from Stauffer (1922).

Coastal: Coastal prefecture. Taken from CHGIS (2016).

Treaty port: Treaty port prefecture. Taken from Nield (2015). ln(*Land area*): Land area. Taken from CHGIS (2016). ln(*River dist*): Distance to the nearest river. Taken from CHGIS (2016).

North: Latitude>26.9. Taken from CHGIS (2016).

pcapital: Provincial capital dummy. Taken from CHGIS (2016).

Chong: Traffic frequency. Taken from Zhao (1928).

Fan: Important in administrative businesses. Taken from Zhao (1928).

Pi: Difficult to tax. Taken from Zhao (1928).

Nan: High in criminal incidents. Taken from Zhao (1928).

Newspaper: Newspapers per capita in 1911. Taken from Bai and Jia (2016).

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