The Long Shadow of the Imperial Examination System and the Historical Root of "Needham Puzzle" and the Chinese Growth Miracle

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The Long Shadow of the Imperial Examination System and the Historical Root of "Needham Puzzle" and the Chinese Growth Miracle

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Abstract

Why China was not the origin of the Industrial Revolution but rose from imperial dynasties and experienced a growth miracle in the past four decades? We find that its root is China's imperial examination system (keju), which explains the fall and rise of historical, modern, and contemporary China. Using three instrumental variable approaches, we find that keju significantly facilitates contemporary innovation and business creation, by raising the contemporaneous level of human capital, shaping an innovative and productive culture, and fostering efficient institutions. Keju had positive effects on the development of modern China before the People's Republic of China era, but its effects were most salient after the economic reform in 1978. In historical periods, keju diverted talents away from scientific/technological sectors, leading to sluggish development in the Ming and Qing dynasties.

JEL Classification: D22, E24, J24, N35, O31

Keywords: imperial examination system, human capital, culture, institution, innovation, business creation, China

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1 Introduction

The famous "Needham Question" ("Needham Puzzle") asks: "Between the first century BC and the fifteenth century AD, Chinese civilization was much more efficient than occidental culture in applying human natural knowledge to practical human needs ... so why was China not the birthplace of modern science...or the Industrial Revolution (Needham, 2013)?" However, on the other hand, the sluggish development in these historical periods provides a sharp contrast with the growth miracle in the past four decades of contemporary China. In this paper, we provide a consistent narrative that associates the imperial examination system (keju), an incredibly long-lived institution lasting for thousands of years in Imperial China and administered for the purpose of selecting candidates for the state bureaucracy, to both the lag in economic and scientific development in the Ming-Qing dynasties and the growth miracle of the past four decades of contemporary China. Keju was thought to undermine scholars' creative and critical thinking by incentivizing them to focus on answering exam questions in a rigid fashion (Lin, 1995; Cho, 2007; Zhu and Chang, 2019), thus misallocating top talents to the stiff examination and bureaucratic system (Bai, 2019).[1] However, when keju is no longer in effect to incentivize talents,[2] it leaves modern and contemporary China with three historical legacies—a higher level of human capital, a more productive, innovative, and open-minded culture, and a market-friendly institution[3] that are all conducive to innovation, entrepreneurship, and, economic growth. These legacies, together with benevolent and market-oriented economic policies after the economic reform and opening up in 1978, led to the growth miracle of contemporary China.

Using the number of contemporary patent applications as a measure of innovation intensity, the number of firm entries as a measure of business creation, jinshi (the highest qualification in the imperial exam) density as a measure of the influence of the exam, and the river distance to the nearest printing materials (pine and bamboo) as the instrumental variable following Chen et al. (2020), we find that increasing jinshi density by 1% raises the number of contemporary patent applications by approximately 1%. The idea behind the instrumental variable is that such a distance measures the cost of obtaining materials for exam preparation and, such, is a strong predictor of exam success. For robustness checks, we also exploit exam transportation costs and weather shocks as the instruments, and the results are still qualitatively similar to the baseline results. The exclusion restriction holds for exam transportation costs and weather shocks especially when **conditioning on key socioeconomic factors**, such as economic prosperity,

[1]The "eight-legged essay," an important element of the exam, is an example. It does not involve any test on scientific knowledge and analytical reasoning that is relevant to scientific discoveries.

[2]In modern and contemporary China, the talent allocation mechanism is the college entrance exam that involves tests on science and analytical skills, resembling that in Western society.

[3]The institution and the culture are based on the high level of human capital. This is why the role of human capital, culture, and institutions cannot be separated and quantified using reduced-form regressions from one another.

and provincial fixed effects that absorb all provincial-level variations. Thus, the instruments are plausibly uncorrelated with **leftover** unobservables.

As for mechanisms, we find the most essential channels underlying this positive effect are threefold: (1) keju facilitates the accumulation of human capital, which is an important ingredient for innovation (Akcigit et al., 2020). This channel echoes the main finding of Chen et al. (2020), who establish a causal relationship between keju and modern-day educational attainments. (2) Keju shapes a productive, innovative, and open-minded culture, leading to personal characteristics and social values that are beneficial for both knowledge and business creation. (3) Keju fosters a mature and market-oriented institution, by cultivating better-educated local leaders who in turn implement better-informed policies that result in a more efficient market and business environment. These three channels highlight the important role of keju in accumulating intangible human, social, and political capital. In particular, the culture and institution are built upon and complementary to the accumulation of human capital (Acemoglu et al., 2014), which is a fundamental factor for economic growth (Romer, 1989). However, since the role of these three legacies goes hand in hand, it is infeasible to quantify their effects using reduced-form regressions. Finally, there is already abundant empirical evidence and theoretical arguments indicating the positive role of human capital (Wei, 2008; Whalley and Zhao, 2013), cultures (Zapalska and Edwards, 2001; Naughton, 2006), and institutions (Clarke et al., 2008; Xu, 2011) in the Chinese growth miracle, all of which also suggest the important role of keju and its historical legacies, closing this chain of logic.

To explain the sluggish economic and scientific development in the Ming-Qing dynasties, we focus on the role of keju in incentivizing talents in historical China. As Lin (1995) and Bai (2019) argue, keju diverted talents to the rigid thinking pattern that was valued by the examination system and allocated them to the bureaucratic system, not the scientific and business sectors.[4] We collected data on whether each jinshi also worked as a scientist or technician (they can rarely be an entrepreneur or businessperson) or whether his family member did so, and we define such jinshi as a science-related one. Such jinshi were either directly or indirectly related to science and technology, and we argue that the share of non-science-related jinshi serves as a measure of the intensity of talent misallocation.[5] If more jinshi were not science- and technology-related, then there was a high level of talent misallocation since fewer elites were incentivized to engage in science- and technology-related endeavors. We find that the share of non-science-related jinshi density is both strongly and negatively associated with a wide array of indicators of historical

[4]The role of talent misallocation mechanism was reinforced by the social values that being an intellect and succeeding in keju was highly endorsed, whereas being a scientist, technician, and businessman was considered as a menial job.

[5]By definition, the share of top talents, or those jinshi, who engage directly or indirectly in science and technology should serve as a valid measure of the distortion of incentives or misallocation.

development. Therefore, keju misallocated talents, resulting in sluggish historical scientific and economic development.

In the historical process of China, we find that keju played an important role in multiple time periods. First, jinshi density is positively related to the number of revolutions and revolutionists that led to the downfall of the Qing Dynasty. This result is consistent with the argument that the removal of the historical keju exam facilitated revolutions (Bai and Jia, 2016). Second, keju contributed to the rise of Kuomintang (KMT) and the Republic of China (RoC). Finally, keju also contributed to the rise of the Chinese Communist Party (CCP) and the People's Republic of China (PRC). These facts are consistent with the role of keju which fostered the accumulation of human capital and shaped an open-minded culture that embraced Western ideologies and nurtured revolutionists and political activists.[6] The positive effects of jinshi density on various economic outcomes are most salient after the economic reform and opening up in the PRC era,[7] consistent with the expedited economic growth during the same period, and the complementary role of benevolent economic policies and keju's historical legacies. Thus, keju can explain the rise of modern[8] and contemporary China.

We would compare our paper to Chen et al. (2020) and Bai (2019) and emphasize our differences. Compared with Chen et al. (2020), we focus on the effects of keju on other outcome variables than human capital; we also use the share of science-related jinshi density as a measure of talent misallocation. Same with Chen et al. (2020), we both use the distance to printing materials as an instrument, but in our paper, we also use exam transportation costs and weather shocks as instruments. Compared to Bai (2019), we both argue that keju led to the sluggish development of historical China. However, in our paper, we also combine this argument with another one that when keju no longer incentivizes talents, it leaves contemporary China with three historical legacies that can explain the growth miracle of the past four decades.

This paper speaks to four strands of the literature. First, it is related to the literature on the determinants of innovation.[9] In a seminal paper, Aghion et al. (2005) argue for a U-shaped relationship between competition and innovation. Following this line of research, Aghion et al. (2009) and Aghion et al. (2013) argue that firm entry and ownership are two important factors for innovation. Chen et al. (2021) focus on China, arguing that government policies have significant effects on the R&D behavior of Chinese firms. However, there are few papers on the effect of human capital and institutions on innovation (the only three exceptions are Waldinger, 2016, Akcigit et al., 2020, and Biasi and Ma, 2022). Our paper fills this gap.

[6]We provide several examples of such revolutionists and political activists in Section 3.

[7]We run the same regression using subsamples of different periods, and the effects are strongest for the post-1978 economic reform period in the PRC era.

[8]Modern China is defined as the era of RoC, whereas contemporary China is defined as the era of PRC.

[9]Cohen (2010) provides a decent summary of the empirical research on innovation.

Second, this paper contributes to the literature on the persistent impacts of institutions on social values and various economic outcomes. Acemoglu et al. (2001) establish the causal effects of historical colonial policies on modern-day economic development. Dell (2010) argues that the labor coercion system in Peru is directly tied to the country's contemporary level of human capital and income. Political institutions such as communist regimes affect preferences and attitudes toward public goods provision (Alesina and Fuchs-Schündeln, 2007). Religious institutions make individuals more risk-averse and different religious norms have different effects on preferences toward public goods provision (Benjamin et al., 2016; Noussair et al., 2013). Our paper echoes this line of research by documenting that keju, as a persistent institution, nurtures social value that respects education, knowledge, and science. Our paper also speaks to Nunn and Wantchekon (2011) and Voigtländer and Voth (2012), both of which argue for the persistence of important historical events on modern outcomes.

Third, this paper contributes to the literature on "Needham Puzzle." Brandt et al. (2014) develops an integrated framework for understanding how deeply embedded political and economic institutions that contributed to a long process of extensive growth before 1800 subsequently prevented China from capturing the benefits associated with the Industrial Revolution. Landes (2006) reviews the reasons why historical China fell behind Europe in science and technology starting from the Song Dynasty. Cantoni and Yuchtman (2013) attribute the sluggish development of historical China to the quality of human capital investment. Compared to the existing literature, this paper novelly associates both the fall of historical China and the rise of modern and contemporary China to keju, thus providing a consistent historical narrative.

Finally, this paper contributes to the literature on the persistent effects of the imperial examination system (keju) in China. Bai and Jia (2016) find that the abolishment of keju is an important reason for political instability in late Qing China. Hao et al. (2022) show that keju abolishment exacerbates local government corruption, leading to more anti-elite protests. Chen et al. (2020) study the long-term effects of keju on human capital accumulation and find that keju has positive causal effects on human capital. Bai (2019) shows that keju serves as an institutional obstacle to the pursuit of modernization and that the abolition of keju induces more modern firms and overseas exchanges. This paper builds on these papers in terms of empirical strategies but studies the effects of keju on new outcome variables: innovation and firm dynamics. The main channel found in the empirical analysis echoes that found in Chen et al. (2020). Last but not least, we document the talent misallocation effect of keju, which echoes the recent literature (Bai, 2019; Hsieh and Klenow, 2009).

The rest of this paper is organized as follows. Section 2 discusses the institutional background. Section 3 establishes the conceptual framework. Section 4 describes the data. Section 5 introduces the empirical strategies. Section 6 reports and analyzes the empirical results. Finally, Section 7 concludes.

2 Background

The Chinese imperial examination system, known as keju, was initially established during the Song dynasty (circa 960–1276). However, it did not become fully institutionalized until the Ming dynasty (circa 1368–1643). The system remained in place until 1905, a few years before the fall of the last imperial dynasty, the Qing dynasty (circa 1644–1911), in 1911.

The imperial exam had three levels. The entry level was the prefectural exam, with successful candidates receiving the title of shengyuan. The next level was the provincial exam, open only to shengyuan. Those who passed were awarded the title of juren. Finally, only those with the juren title could take the jinshi exam, the highest and final stage of the imperial exam. Passing this exam granted the jinshi title and a guaranteed government position. These exams were held at different locations, and the distances to these locations are used as a measure of transportation costs and instrumental variables in our analysis. We use the density of jinshi as the main independent variable in the empirical analysis, with the densities of juren and shengyuan used as robustness checks.

China's imperial exam system (keju) operated under a quota system. The quotas for jinshi were based on the population of each province and their historical success in the exams, with these quotas remaining relatively unchanged over time. Throughout most of the Ming-Qing period, these quotas were stable, and it was uncommon for provinces or prefectures to lobby for an increase. This stability rules out the possibility that local lobbying efforts influenced the jinshi density.

China's imperial exam had four essential features. First of all, it served as the key mechanism to incentivize and allocate talents. In particular, it induced talents to engage in learning Confucianism and answering rigid exam questions. Compared to Western society, top talents were diverted away from science and technology and commercial sectors that are conducive to economic and scientific development. The second most important was that it had a wide group of participants among the male population. It was open to all males no matter their social background. This implies that someone whose ancestors had never passed even the lowest level of the exam had a chance to participate in the imperial exam if he passed each level of the exam in the above-mentioned sequence. The second feature was that the organization and participation of imperial examinations rarely involved corruption. To prevent examiners from recognizing a particular exam taker through his handwriting, all exam scripts were hand-copied first and graded by eight examiners, who could not identify candidates' identities. Moreover, the examiners would be removed from office if they were found to have favored a particular candidate in their grading or would even be given the death penalty, which was serious enough to prevent corruption. Finally, given that all exam takers were allowed to take the exam more than once, China's imperial exam system was extremely competitive. The probability of getting the jinshi was no more than 2%, whereas for the juren and shengyuan it was about 6% and 18%, respectively.

The intensity of competition and the high stake of the keju examine significantly incentivized top talents in China. In particular, keju diverted those talents to the rigid examination system, forcing them to recite ancient philosophers' (mostly Confucian scholars') thoughts and speeches. *Four Books and the Five Classics* (Si Shu Wu Jing) were the textbooks for exam preparation, and their accessibility largely determined the success of the exam takers. This is the reason why we choose the shortest river distance to printing ingredients (pine and bamboo) as the instrumental variable for identification, following Chen et al. (2020). In all, the keju exam constrained the scientific development in the Ming-Qing dynasties, providing an explanation for the "Needham Puzzle."

The role that keju played in shaping the sluggish development of the Ming-Qing dynasties was the misallocation of top talents in China. Diverting talents out of the science and business sectors resulted in the lack of skilled labor supply that is a necessary condition for scientific and economic development. When such misallocation was removed, keju left three historical legacies, human capital, cultures, and institutions that led to the growth miracle after the economic reform in 1978, when the central leadership of China started implementing the right policy to "make the incentives right." Thus, China seized the opportunity to grow fast. In historical periods, however, without an insightful central leadership that implemented benevolent policies and with the constraints of keju, China missed two opportunities for its own Industrial Revolution. The first was that China could initiate its own industrial revolution given its technological advantage in the Song dynasty, and the second was that China could catch up with Europe when they started the revolution and modern technology started to diffuse into China. We will discuss the conceptual framework in more detail in Section 3 below.

3 Conceptual Framework

In this section, we describe the role of keju in explaining (1) the growth miracle of contemporary China in the past four decades; (2) the sluggish innovation and scientific development in the historical Ming-Qing periods; and (3) the transition from historical China to modern and contemporary China. To explain the growth miracle of contemporary China, we emphasize the effects of keju in human capital accumulation, shaping an innovative, productive, and open-minded culture, and fostering market-friendly institutions. To explain the sluggish development in the Ming-Qing dynasties, we emphasize the role of keju in directing talents in the bureaucratic system, not innovation and entrepreneurship. Finally, to explain the transition from historical China to modern and contemporary China, we focus on the role of keju in nurturing revolutionists and political activists who stemmed from an open-minded and inclusive culture that embraced Western ideologies.

To begin with, keju facilitates modern-day human capital accumulation. This is the main finding of Chen et al. (2020). The reasoning is that keju cultivates penmanship and an atmosphere that values education and knowledge. The latter is also related to the second role of keju, which is shaping a culture that is conducive to innovation and entrepreneurship. In modern-day China, talents are not selected into the bureaucratic system via a rigid examination system such as keju,[10] and yet the cultivation of penmanship and accumulation of human capital by keju gives birth to many talents that are innovative and productive and contribute significantly to economic development. For example, the Yangtze River Delta (Jiangsu, Zhejiang, and Shanghai) experienced great success and a high level of keju exposure in historical China, and it is also home to many famous scientists and entrepreneurs in contemporary China. Moreover, our documentation that human capital leads to innovation and firm creation, is consistent with the empirical evidence and theoretical arguments provided by the literature that currently emerges (Waldinger (2016); Akcigit et al. (2020); Biasi and Ma (2022)). There is also empirical evidence and theoretical arguments indicating the positive role of human capital (Wei, 2008; Whalley and Zhao, 2013) in the Chinese growth miracle.

Second, as Elman (1991) and Chen et al. (2020) argue, keju created a culture that values education and knowledge. In contemporary China, after the economic reform in 1978, economic development became a primary goal of the government and the society. After the college entrance examination was resumed, talents were selected for higher education whose future careers lay in top positions in the business or science and technology sectors. Thus, the culture shaped by keju encourages people to pursue knowledge and education, both of which are a foundation for innovation and entrepreneurship. Such an argument is consistent with the empirical evidence that keju builds personal characters and social values that are conducive to innovation and entrepreneurship. Moreover, such a culture also fosters human capital accumulation, and, its effects depend on the level of human capital. A high level of human capital itself posits more social value on education and innovation, which in turn contributes to a higher level of human capital. Therefore, it is infeasible to separately estimate the contributions of human capital and culture. We will discuss the related empirical evidence in Section 6.5.2. Finally, there is already abundant empirical evidence and theoretical arguments indicating the positive role of cultures

[10]The working mechanism to allocate talents is the college entrance exam combined with college application systems that resemble that in Western countries.

(Zapalska and Edwards, 2001; Naughton, 2006) in the Chinese growth miracle, suggesting the important role of keju and its historical legacy.

Third, keju also fosters market-friendly institutions in contemporary China. Such institutions also rely on the foundation of a high level of human capital and a productive culture, which are complementary to institutions. With a higher level of human capital and a more productive culture, efficient institutions can emerge more easily. On the one hand, the accumulation of human capital by keju cultivates more capable political leaders, who are the ones who execute efficient institutions. As we will document later, cities with a higher level of success in the keju exam give birth to city mayors or city Party Secretaries with higher educational attainment and with a science, engineering, or economics major, and this is also based on a high level of human capital and a benign culture. On the other hand, these city leaders, in turn, implement policies that are better-informed and more market-oriented, fostering a market-friendly institution that helps innovation and business creation. Also, these policies can especially take effect in a social environment with a productive and benevolent culture. This is consistent with the finding in Chen et al. (2020), whereby keju accumulates political capital that may be translated into better-informed politicians and policies that facilitate economic development. Finally, there is already rich empirical evidence and theoretical arguments suggesting that institutions (Clarke et al., 2008; Xu, 2011) play an important role in the Chinese growth miracle, finishing this chain of reasoning.

According to the above analysis, keju can explain the growth miracle in contemporary China, since it accumulates human capital, shapes innovative and productive cultures, and fosters market-oriented institutions. However, all these mechanisms are not at play when talents are misallocated so that most of the nation's endowment of human capital is not devoted to economic and scientific development, which arguably became one of the most dominant obstacles to hinder development (Lin, 1995; Bai, 2019). In the Ming-Qing dynasties, keju diverted top talents into preparing for the rigid examination system and a thinking pattern that did not encourage innovation and business creation. At that time, only a small proportion of successful exam takers (jinshi) (and/or their close relatives) were also scientists or technicians, who made significant contributions to scientific development in historical China. Although there were several outstanding scientists who also succeeded in the keju exam, the absolute number was small so the overall contributions were not comparable to the Western world. In addition, as we will document below, the share of non-science-related jinshi is strongly and negatively associated with indicators of economic and scientific development of the Ming-Qing eras. Therefore, in this paper, we provide a consistent historical narrative that can explain the sluggish development of the Ming-Qing dynasties and contemporary China's growth miracle, both through the lens of a long-lasting institution, keju.

Therefore, due to the above mechanisms, keju has been playing a significant role in the whole process in the fall and the rise of historical, modern, and contemporary China. We already explained the logic why keju led to the sluggish historical development but the contemporary Chinese growth miracle. What to add then is that the positive role of keju should be more salient combined with benevolent economic policies, especially so after the economic reform of contemporary China after 1978. This is due to the fact of the complementary role of human capital, cultures, and institutions (Acemoglu et al., 2001; Acemoglu et al., 2014), since keju has positive effects on all three factors, and the economic reform and opening up provided an effective policy and institutional setting in which these factors can take effect to facilitate economic growth.

Finally, keju also contributed to several transition phases in Chinese history. Since keju accumulated human capital and fostered an open-minded culture that embraced ideas and thoughts from Western countries, it nurtured academics, revolutionists, and political activists who contributed to the abolishment of imperial institutions and the overthrow of the Qing dynasty, and also to the rise of Kuomintang (Republic of China) and Chinese Communist Party (People's Republic of China). A salient example is that several leaders in the Hundred Days' Reform and the 1911 Revolution during the late Qing era, the majority of whom (such as Kang Youwei, Liang Qichao, and Tan Citong) once succeeded to some extent in the keju exam, but they were also heavily affected by and were open to Western ideologies, and, thus, led to revolutions and finally the downfall of the Qing dynasty. Moreover, keju also cultivated political leaders for Kuomintang and the Chinese Communist Party. For example, Song Jiaoren, a shengyuan in the keju exam, later became a political leader in Kuomintang and one of the founders of the Republic of China; Chen Duxiu, a jinshi, and Li Dazhao, a gongsheng in the keju exam, both founded the Chinese Communist Party, which later founded the People's Republic of China. Thus, in sum, keju also contributed to the transition of imperial China to modern and contemporary China.

4 Data and Measurements

In the empirical analysis, our unit of observation is (1) cross-sectional at the city level when we use the city-level cross-sectional data, or (2) individual level when we use survey data. We construct our data set using the following several databases. In particular, we map the historical jurisdictions in the Ming and Qing dynasties to modern jurisdictions according to geographical scopes, and, thus, link historical data to modern outcomes.

4.1 Civil Service Examination (Keju) Influence Data

The most important independent variable in the regression analysis is regional exposure to the influence of the imperial examination system (keju), especially whether prefecture cities perform well on the exam during the Ming-Qing period. The qualification for the imperial exam consisted of three levels, including jinshi, juren, and shengyuan. We choose the density of jinshi as the primary measure of keju influence because it was the highest attainment and hence its impacts are the most pronounced. We also perform a robustness check using data on the density of juren and shengyuan—the next two qualifications down.

The jinshi data are obtained from Chen et al. (2020), who in turn obtain the data from Zhu and Xie (1980) Ming-Qing Jinshi Timing Beilu Suoyin (Official Directory of Ming-Qing imperial exam Graduates). Chen et al. (2020) enumerate such information as the names and birthplaces of jinshi, and examination location (in the event that this differed from a scholar's birthplace). The Directory contains a complete list of all the 46,908 jinshi who sat a combined 242 imperial exams between 1371 and 1904 (a period of just over 500 years) across 278 Chinese historical prefectures, corresponding to 272 municipalities in contemporary China.

As some prefectures were more populous and larger than others, we normalize the number of jinshi by the prefecture population (in units of 10,000) based on data compiled by Cao (2000) and Cao (2015), the only data source at the prefecture-level for various periods spanning both the Ming and Qing dynasties. Following Chen et al. (2020), we use the average population of the following seven years: 1391 (Ming), 1580 (Ming), 1776 (Qing), 1820 (Qing), 1851 (Qing), 1880 (Qing), and 1910 (Qing). We also take a natural log of jinshi density. To deal with observations with value zero, we define keju influence as $\log(1 + jinshi/population)$.[11]

4.2 Measuring Talent Misallocation

In our paper, we also investigate the effects of talent misallocation. To measure this, we collected data on whether each jinshi also worked as a scientist or technician or whether his close relatives (including (grand)fathers, (grand)sons, siblings, in-laws, and nephews) did so. We define such jinshi as a science-related one, and use this variable as a measure of the inverse of the distortion of talent incentivization. If a jinshi himself also worked as a scientist or technician, then he was directly related to science, which reflects an outcome of talent allocation. A salient example of such a science-related jinshi is Xu Guangqi, who was a jinshi, and also an agronomist, astronomer, mathematician, and writer during the Ming dynasty. He was a collaborator of the Italian Jesuits Matteo Ricci and Sabatino de Ursis and assisted in their translation of several

[11] We also use $\log(0.01 + jinshi/population)$ or $arcsinh(jinshi/population)$ as alternative measures and the results remain robust.

classic Western texts into Chinese, including part of Euclid's Elements. On the other hand, if a jinshi's close relatives worked as scientists or technicians, then this jinshi was indirectly related to science. A salient example is Zhao Shankuo, whose nephew Zhao Dongchuan was a scientist in the Qing dynasty. Such indirectly science-related jinshi also serves as a measure of how the elite class was devoted to the science and technology sectors, since family members could exert peer effects in career choices in science and technology, and, their involvement in science and technology captures talent allocation and incentives shaped by cultures and institutions, in particular, keju.

The share of non-science-related jinshi, which we use to measure talent misallocation, is calculated as the ratio of the number of jinshi who were neither directly nor indirectly related to science over the total number of jinshi. We calculate the share for each prefecture city in our sample. As we argued previously, it should be positively associated with the degree of talent misallocation. Since jinshi represented the top talents and the elite class in historical China, if fewer jinshi were devoted to science, the distortion of incentives was stronger and talent misallocation was more salient. To obtain information about each jinshi's career and family background, the data sources we exploit are Wikipedia and "A Compilation of Family Biographies of Imperial Examination Figures in the Qing Dynasty." We checked whether each jinshi was science-related manually using these sources, and counted the number of such jinshi for each prefecture city. Relevant information will be directly provided by these sources if a jinshi is either directly or indirectly related to science, since on the one hand, being a historically famous scientist and technician can be easily identified and such information constitutes an important part of each jinshi's biography. In the case of being indirectly related to science, a note will be provided by the data sources we rely on if a close relative of the focal jinshi worked as a famous scientist or technician. The share of science-related jinshi is 10.36%. The spatial distribution is shown in Figure B1. Of all science-related jinshi, about 56.4% are indirectly related to science.

4.3 Patent Data

To measure innovation, we use Chinese patent applications. This data is provided by the China National Intellectual Property Administration. The Center of Enterprise Research (CER) at Peking University matched this database with the firm registration database, so we have information regarding what firms applied for what patents. Using the period of 2007-2015, we aggregate the data at the city level, and calculate the number of patent applications for each city. The related summary statistics are shown in Table A1. See Appendix C for more details.

4.4 Firm Data

The main interest of our analysis is firm dynamics in China, especially firm entry and exit, which are calculated using the Chinese firm registry database. This database provides registry information of all firms in China (about 20 million firms), including location, year of establishment, year of exit (if any), and value of registry capital[12]. From individual registration records, we can calculate how many firms enter and exit in a specific city during the period from 2007-2015. The summary statistics for log(entry) and log(exit) are shown in Table A1.[13] We use the total size of the registry capital of all firms that register or deregister in a certain city to measure entry and exit; this is the main outcome variable in the descriptive analysis. We provide further details of data compilation in Appendix C.

We use firm data from the annual waves of the National Tax Statistics Database (NTSD), which are jointly conducted by the State Administration of Taxation and the Ministry of Finance. The NTSD data collection effort was initiated in 1985 for tax enforcement purposes. However, the sampling methods and variables used were inconsistent until 2007, when the government significantly increased the sample size and made the variables consistent across years. Roughly 700 thousand firms are surveyed each year, approximately 80% of which are key firms and are medium and large in size. The remaining 20% are selected using a stratified random sampling method. The overall tax receipts reported by the sampling firms accounted for 75% of the aggregate national tax revenue in 2014.

All sampled firms fill out three forms. The first is an information form that records basic information, including taxpayer identification number, name, address, ownership type, industry, and opening year and month. The second is a tax form that contains tax as well as financial information of firms, including a balance sheet, income statement, and cash flow statement. The third is a goods and services form that includes the average price of products or services sold, the quantity of products, and their total domestic sales and exports. For this study, we use the 2007 to 2015 waves of the NTSD.

Using the NTSD, we calculate the average firm performance in a city, including the average revenue per labor, average profit per labor, and average export per labor. The summary statistics of these variables are shown in Table A1.

4.5 China Family Panel Survey

The China Family Panel Survey (CFPS), which was launched in 2010 by the Institute of Social Science Surveys (ISSS) with Peking University, exploits a multi-stage probability sampling

[12] According to Chinese Business Law, registry capital does not refer to a firm's fixed assets; instead, it is proportional to the firm's scale (and assets).

[13] All observations do not contain 0 at the city level, so we can use $\log(Y)$ directly instead of $\log(1+Y)$.

procedure. It is nationally representative, covering 162 counties or districts (counties thereafter) across 25 mainland provinces that represent 95 percent of the total population in China. During the first wave, the CFPS completed interviews with 33,600 individuals living in 14,798 households. These individuals were re-interviewed biennially. The CFPS provides information on respondents' opinions on knowledge and education, personal beliefs on society and attitudes toward social values, and the personalities of surveyed children. We utilize such information to measure cultures, which can be a factor that contributes to the growth miracle of contemporary China and is under the influence of historical keju. The summary statistics can be found in Table A1. We leave details of the construction of measures and variables in Appendix C.2.

4.6 Other Dependent Variables

We also use other data sources to construct dependent variables. First, we use the China Biographical Database Project (CBDB) data set to calculate the density of famous scientists in the Ming and Qing dynasties. Second, we use information on listed firms and the curriculum vitae of the CEO of the firm, and the first six digits of the ID card of the legal representative of registered firms, to calculate the density of CEOs and firm owners in different cities. Third, we downloaded the government work report of each city government during 1994-2019. We calculate the share of keywords related to market order, business environment, judicial quality, financial market, and corruption, and use them as the dependent variable. The summary statistics can be found in Table A1.

4.7 Control Variables

The choice of control variables also follows Chen et al. (2020). Typically, a prefecture that was more economically developed was also likely to produce more jinshi. Without reliable GDP or economic prosperity data, we follow Bairoch (1988) by using population density and urbanization rate as proxies for the level of local economic development. We use the average population density between 1393 and 1910 and the average share of the urban population between 1393 and 1920 as proxies for the same period for which the jinshi density is measured.

Given that China was still mainly an economy where the agricultural sector dominates, during the sample period, we measure a prefecture's prosperity using its potential agricultural productivity (yields of crops that are suitable for cultivation) based on the Caloric Suitability Indices developed by Galor and Özak (2016).

We also control for several major characteristics of geography, or more specifically, distance to the nearest coast and terrain ruggedness. Distance to the coast is essential for two reasons: (1) prefectures located on the coast were likely to be exposed to and thus benefit from Western technology, ideology, knowledge, and trade, and (2) coastal areas are sources of immigration in modern-day China. Distance to the coast is measured as the distance between the centroid of a prefecture and the closest point on the coast. We also control for terrain ruggedness, which can have a long-lasting impact on the long-run economic development via its direct effect on development, or through its interaction with other economic events. The index of terrain ruggedness is constructed by calculating the difference in elevation between contiguous cell grids using data from the United States Geological Service (USGS).

Finally, we control for modern-day levels of economic development, measured by the average satellite nightlight density in 2010 at the prefecture city level (Henderson et al., 2012).

5 Empirical Strategies

5.1 Instrumental Variable 1: Distance to Printing Materials

The main identification strategy in the empirical analysis is an IV-2SLS strategy, with the following specification:[14]

$$y_i = \beta \widehat{Jinshi}_i + X_i \gamma + \lambda_p + u_i, \tag{1}$$

where y_i is the outcome variable in city i, including the log of patent applications, log R&D, log new entrants, and so on. $\widehat{Jinshi}_i$ is the predicted value of jinshi density in city i. β is the parameter of interest. X_i is a vector of controls, including log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates.[15] λ_p is provincial fixed effects. Finally, u_i is the error term. We cluster the standard error at the provincial level in all regressions.

The first-stage regression is as follows:

$$Jinshi_i = \alpha DistancePrinting_i + X_i \gamma + \lambda_p + v_i, \tag{2}$$

where $DistancePrinting_i$ is the river distance between city i and the nearest place that produces printing materials (pine and bamboo). We follow the specification in Chen et al. (2020) and the idea of the instrumental variable is as follows. The *Four Books and the Five Classics* were the "textbooks" for China's imperial exam. For any exam-taker to be successful in the exam he would not only have to memorize its contents but also master them to analyze related arguments. This required not only access to the hard copies of the textbooks but also paper-based materials

[14]We follow Chen et al. (2020) to construct the specification. The intuition and the validity are explained in Section 2.

[15]We use the same set of controls as in Chen et al. (2020), so that our results are comparable.

that explained these texts and taught the method of writing the rigid "eight-legged essay." However, access to reference books varied enormously from one prefecture to another in terms of prohibitive transport and trade costs between localities. Because the availability of materials for textbook production is strongly and positively associated with success in the exam, the instrumental variable satisfies $cov(Jinshi_i, DistancePrinting_i) \neq 0$. On the other hand, since places that produce pine and bamboo are determined by natural conditions, it is very likely that the IV is exogenous in the sense that it does not directly affect modern-day innovation and firm dynamics. Therefore, the instrumental variable satisfies $cov(u_i, DistancePrinting_i) = 0$. To validate this argument, we also test whether the instrumental variable is correlated with the distance to other places, like the national capital, the provincial capital, and the coast. It is reassuring that there are no discernible correlations. Chen et al. (2020) also demonstrate that our instrumental variable is uncorrelated with various indicators of historical economic prosperity, agricultural suitability, geography, and 2010 night-time light intensity. Additionally, Chen et al. (2020) show that the locations of pine and bamboo forests, as natural habitats, are exogenous. To avoid repetition, we do not present the related results in this paper.

Finally, we use this same IV for non-science jinshi share. The exclusion restriction holds for the same reason as we use it for jinshi density. The relevance condition holds since this IV also measures the relative cost of becoming a scientist or technician when one is already a jinshi. In particular, being more distant to printing materials increased the relative cost of engaging in science and technology, and, thus, increased the share of non-science jinshi, as Table A2 suggests, and, thus, validating the relevance condition. It is further supported by a large first-stage F-statistic.

5.2 Instrumental Variables 2: Transportation Costs of Exam

We use the transportation cost of participating in exams as the second instrument. The cost is determined by the geographic locations of the focal city and the exam city of different exam levels. To allow for flexible functional forms, we do not aggregate the distances into one single indicator, but use the log distance to all three levels of keju exam as the set of IVs. The cost is a valid instrument because it is negatively related to the success of keju and unrelated to unobservables **conditional on key socioeconomic factors.** Thus, we estimate the following first-stage regression:

$$Jinshi_i = ExamTransportationCost_i\alpha + X_i\gamma + \lambda_p + v_i, \tag{3}$$

where $ExamTransportationCost_i$ is a vector of the distance of city i to the exam location at various levels. This vector is a measure of exam transportation costs. Moreover, conditional on key socioeconomic factors such as economic prosperity, the transportation cost should be orthogonal to **leftover unobservables.** Thus, the identification assumption, or exclusion restriction, is satisfied: $cov(ExamTransportationCost_i, v_i) = 0$. We also report the first-stage F-statistic, which is significantly greater than 10. Finally, since the number of instruments is greater than the number of endogenous variables, we also employ a Sargan-Hansen overidentification test (Sargan, 1958; Hansen, 1982), and the results are desirable in the sense that no overidentification is detected.

Finally, we use this same set of IVs for non-science jinshi share. The exclusion restriction holds for the same reason as we use it for jinshi density. The relevance condition holds since this set of IVs also measures the relative cost of becoming a scientist or technician when one is already a jinshi. In particular, being more distant to exam locations increased the relative cost of engaging in science and technology, and, thus, increased the share of non-science jinshi, as Table A2 suggests, and, thus, validating the relevance condition. It is further supported by a large first-stage F-statistic.

5.3 Instrumental Variables 3: Weather Shocks

We use the weather and earthquake shocks as the third instrument. In the following equation (4), $WeatherShock_i$ is a vector of the numbers of droughts and earthquakes. It is a valid instrument because the incidence of droughts and earthquakes is plausibly random. This is especially the case **after controlling for key socioeconomic factors** and that may stem from weather shocks and fixed effects. Therefore, conditional on key socioeconomic factors such as economic prosperity and fixed effects, the weather shocks should be orthogonal to **leftover unobservables.** On the other hand, weather shocks capture the cost of taking exams and the success, since taking exams had to be supported by enough family income that was mainly obtained from the agricultural sector, thus satisfying the relevance condition. Thus, in the following equation, we can establish the exclusion restriction: $cov(WeatherShock_i, v_i) = 0$. We also report the first-stage F-statistic, and it is significantly greater than 10. Finally, since the number of instruments is greater than the number of endogenous variables, we also employ a Sargan-Hansen overidentification test (Sargan, 1958; Hansen, 1982), and the results are desirable in the sense that no overidentification is detected. In sum, we estimate the following first-stage equation:

$$Jinshi_i = WeatherShock_i\alpha + X_i\gamma + \lambda_p + v_i, \tag{4}$$

Finally, we use this same set of IVs for non-science jinshi share. The exclusion restriction holds for the same reason as we use it for jinshi density. The relevance condition holds since this set of IVs also measures the relative cost of becoming a scientist or technician when one is already a jinshi. In particular, experiencing more weather shocks increased the relative cost of engaging in science and technology, and, thus, increased the share of non-science jinshi, as Table A2 suggests, and, thus, validating the relevance condition. It is further supported by a large first-stage F-statistic.

5.4 OLS Estimation

Alternatively, we also estimate the following specification using simple OLS:

$$y_i = \beta Jinshi_i + X_i\gamma + \lambda_p + u_i, \quad (5)$$

where y_i is the outcome variable in city i, including the log of patent applications, log R&D, log new entrants, and so on. $Jinshi_i$ is the actual (instead of predicted) value of jinshi density in city i. X_i is a vector of controls, including log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. λ_p is provincial fixed effects. Finally, u_i is the error term. we cluster the standard error at the provincial level in all regressions.[16]

6 Empirical Results

6.1 Baseline Results

We start the empirical analysis by estimating an OLS specification without controls (except for province fixed effects). The results are reported in Table A3. In columns (1) through (9), where the dependent variables are the number of patent applications, R&D expenditure, firm entry, and firm performance, the coefficients on jinshi density are all positive and statistically significant. Moreover, the economic significance is quite pronounced. For example, increasing jinshi density by 1% raises the number of patent applications by slightly more than 1%.

Next, we estimate an OLS specification with a full set of control variables. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. The coefficients on jinshi density, presented in Table A4, are somewhat smaller than their counterparts in Table A3, but these coefficients are mostly positive and statistically significant. With control variables, increasing jinshi density by 1% raises the number of patent applications by about 0.7%.

[16] The logic of this IV is similar to that of rainfall shocks (Miguel and Satyanath, 2011; Sarsons, 2015).

With our OLS specification yielding qualitatively consistent results, we then estimate equation (3) using an IV-2SLS estimation. The results of the IV-2SLS estimation are shown in Table 1. In columns (1) through (9), the coefficients on jinshi density are positive and statistically significant. The magnitude of the coefficients is in between their counterparts in Table A3 and Table A4. For example, raising the jinshi density by 1% enhances the number of patent applications by approximately 0.9%. The results of the first-stage regressions presented in Table A2 indicate that the instrument relevance condition holds. The first-stage F-statistic is about 115.9, suggesting that weak instruments are not an issue. We also test whether the instrumental variable is correlated with the distance to other places, like the national capital, the provincial capital, and the coast. According to Table A5, there is no such discernible correlation.

For robustness checks, we also use two alternative sets of instruments: exam transportation costs and weather shocks. The results are presented in Tables 2 and 3. The coefficients are both qualitatively and quantitatively similar to the counterpart in Table 1. The results of the first-stage regressions presented in Table A2 indicate that the instrument relevance condition holds. Moreover, the first-stage F statistics are larger than 10, and the overidentification tests produce desirable results.[17]

We next estimate the same IV-2SLS specification using juren and shengyuan (the next two qualifications below jinshi), as the main independent variable. We report the estimation results for juren in Table B1 and shengyuan in Table B2. In Table B1, the results are qualitatively similar to those for jinshi: in columns (1) through (9), all coefficients on the juren density are positive and statistically significant. The magnitude is also quite close: increasing juren density by 1% raises the number of patent applications by approximately 1%. However, the results for shengyuan are not the same as jinshi and juren, perhaps because it is much easier, relatively speaking, to earn shengyuan status, making shengyuan density insufficient to represent the influence of the imperial examination system well.

The data used in the above analysis covers the period of 2007-2015. We then separately estimate the effects of keju on three main outcomes, number of patent applications, R&D expenditure, and number of new entrants, using yearly data for each year of the sample period.[18] The results are reported in Figures B2,B3, and B4. The plotted coefficients imply that the effects of keju on modern-day outcomes do not change with the choice of the sample period. We also use the sample period of 98-07 and report the related results in Table B3. The results are also qualitatively similar. Moreover, we use the jinshi density in different historical periods as the main independent variable, and the results, shown in Figure B5, B6, and B7, indicate that the

[17] The p-values in Tables 2 and 3 are 0.488 and 0.336, respectively, failing to reject the null hypothesis.

[18] However, when we zoom out and focus on longer periods, the specific time period matters for the salience of the effects. For example, the effects are the most salient after the economic reform in 1978 of the PRC era.

Table 1: Baseline results: Distance to printing materials as IV

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
		IV: Distance to printing materials	
log jinshi density	0.996***	0.882***	0.638***
	(0.159)	(0.238)	(0.159)
First-stage F statistic		115.9	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.739	0.657	0.681

	(4)	(5)	(6)
	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L
		IV: Distance to printing materials	
log jinshi density	0.453**	177.0***	3.067**
	(0.192)	(66.19)	(1.555)
First-stage F statistic		115.9	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.644	0.449	0.795

	(7)	(8)	(9)
	Avg. export/L	log(Patents per firm)	log(R&D per firm)
		IV: Distance to printing materials	
log jinshi density	21.39***	0.370***	0.256*
	(7.492)	(0.0966)	(0.144)
First-stage F statistic		115.9	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.574	0.721	0.540

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table 2: Baseline results: Exam transportation costs as IVs

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
		IVs: exam transportation costs	
log jinshi density	2.334***	2.452***	1.228***
	(0.667)	(0.597)	(0.398)
First-stage F statistic		17.10	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.536	0.451	0.528

	(4)	(5)	(6)
	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L
		IVs: exam transportation costs	
log jinshi density	1.864***	371.5**	2.614
	(0.647)	(158.5)	(2.293)
First-stage F statistic		17.10	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.434	0.378	0.795

	(7)	(8)	(9)
	Avg. export/L	log(Patents per firm)	log(R&D per firm)
		IVs: exam transportation costs	
log jinshi density	16.58	0.980***	1.098***
	(16.91)	(0.293)	(0.244)
First-stage F statistic		17.10	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.567	0.592	0.413

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. The p-value for the Sargan-Hansen test is 0.488. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table 3: Baseline results: Weather shocks as IVs

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
		IVs: Weather shocks	
log jinshi density	1.255***	1.322***	0.735***
	(0.458)	(0.408)	(0.253)
First-stage F statistic		17.852	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.724	0.639	0.670

	(4)	(5)	(6)
	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L
		IVs: Weather shocks	
log jinshi density	0.209	69.13	-3.949
	(0.483)	(87.95)	(4.352)
First-stage F statistic		17.852	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.638	0.418	0.722

	(7)	(8)	(9)
	Avg. export/L	log(Patents per firm)	log(R&D per firm)
		IVs: Weather shocks	
log jinshi density	8.637	0.555**	0.623**
	(10.87)	(0.261)	(0.270)
First-stage F statistic		17.852	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.572	0.705	0.526

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. The p-value for the Sargan-Hansen test is 0.336. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

keju exposure in different historical periods all have similar positive effects on innovation and business creation.

Next, we estimate the effects of jinshi density on exit and trademark applications. The results on exit are shown in Table B4. Using an IV-2SLS strategy as above, we show that jinshi density has positive and statistically significant effects on exit. Since the correlation between jinshi density and entry is also positive, such results can be interpreted to suggest that the imperial examination system increases the level of market turnover for modern firms. The increase in exit in cities with a higher jinshi density may be driven by more entry, fiercer market competition, and more creative destruction, as pointed out in Shi (2021) and Barwick et al. (2022). As for trademark applications, the results reported in Table B5 indicate that jinshi density is also positively associated with the number of trademark applications. This is one more piece of evidence that keju facilitates modern-day innovation and business creation.

6.2 The Sluggish Development of Ming-Qing Dynasties

6.2.1 The Role of Talent Misallocation

We now argue that keju diverted human capital into the rigid examination system that inhibits the development of science and technology. We obtain the density of science-related jinshi, those who were or whose family members were scientists or technicians, in Wikipedia and "A compilation of family biographies of imperial examination figures in the Ming/Qing Dynasty." We use the same instrumental variable estimation to assess the effects of the share of non-science-related jinshi density on an array of indicators of historical development.[19] The results of the first-stage regressions presented in Table A2 and the first-stage F statistics indicate that the instrument relevance condition holds. We present the IV estimation results in Table 4. The share is strongly and negatively associated with the density of scientists in the Ming and Qing dynasties, population density, school density, and the number of charitable organizations. When we control for jinshi density and run an OLS specification, the results (in Table B6) are still robust. Thus, keju may explain the sluggish scientific development in historical periods.

We can interpret the effects of talent misallocation on the sluggish development as the **contemporaneous** role of human capital in the process of development, since the talent misallocation and the sluggish development occurred at the same time. This pattern also echoes the role of human capital in economic and scientific development (Akcigit et al., 2020). Although keju fosters modern-day human capital accumulation, as Section 6.5.1 argues, it resulted in a lack of supply of high-skilled labor in the science and business sector in historical China, and,

[19]The instruments are still valid because they capture the incentives to engage and succeed in keju, and contain exogenous variations only.

thus, led to sluggish development in the Ming-Qing dynasties.

6.2.2 The Downfall of the Qing Dynasty

In this section, we examine the effects of Keju on the downfall of the Qing Dynasty. Bai and Jia (2016) find that the abolition of the keju exam ignited revolutions and accelerated the downfall of the Qing dynasty because bureaucratic mobility and access to governmental positions were hindered since keju no longer selects civilians into the bureaucracy. This argument is equivalent to that the more successful a city in the keju exam, the more revolutions would happen since the abolition would incur more changes in incentivizing talents. This argument is corroborated by Table A6, which indicates that the density of jinshi positively affects the number of revolutions and revolutionists and that the density of non-science jinshi negatively affects those. The empirical findings are inconsistent with the argument that a higher level of keju success represents more stringent Confucian thought controls that hindered revolutions. Alternatively, keju may have led to a higher level of human capital and a more inclusive culture that fostered openness to ideas and thoughts from Western countries, not limited to science and technology, and, thus, leading to more active participation in revolution and finally the downfall of the Qing dynasty. For example, several leaders in the Hundred Days' Reform and the 1911 Revolution during the late Qing era, the majority of whom (such as Kang Youwei, Liang Qichao, and Tan Citong) once succeeded in the keju exam, but they were also heavily affected by Western ideologies and institutions, and, thus, led to revolutions and finally the downfall of the Qing dynasty.

6.3 The Rise of KMT/CCP and Republic of China/People's Republic of China

After the Qing Dynasty was overthrown, the Republic of China (RoC) was established by Kuomintang (KMT). Then, RoC was overthrown by the Chinese Communist Party (CCP), which in turn established the People's Republic of China (PRC), which is the contemporary China. In this section, we examine the effects of the keju exam on the rise of modern and contemporary China. We use the number of KMT members, CCP members, new firms, Japan overseas, and newspapers during the RoC period as a measure of the rise of RoC. Table 5 indicates that using the same instrumental variable estimation, jinshi density is strongly and positively correlated with the array of these outcomes. For example, increasing the density of jinshi by 1% raises the number of KMT members by 1.767, about 89% of the standard deviation, and, thus, exhibits a large effect. Moreover, jinshi density is also positively associated with the number of CCP members, and, thus contributed to the rise of CCP and PRC.

Table 4: Keju as a cause of sluggish development of Ming and Qing dynasties

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	log scientist den., Ming	log scientist den., Qing	log pop den.	log school, 1900	Urbanization rate	log charitable org., 1840	log Confucianists
				IV: Distance to printing materials			
log non-science jinshi share	-0.000856***	-0.00119***	-0.107**	-0.231**	-0.00497	-0.352***	-0.316
	(0.000229)	(0.000324)	(0.0490)	(0.0999)	(0.00480)	(0.119)	(0.269)
	(0.000929)	(0.00130)	(0.192)	(0.364)	(0.0172)	(0.462)	(1.031)
First-stage F statistic				25.835			
Province FE	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	272	272
R-squared	0.782	0.782	0.895	0.833	0.718	0.211	0.549
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	log scientist den., Ming	log scientist den., Qing	log pop den.	log school, 1900	Urbanization rate	log charitable org., 1840	log Confucianists
				IVs: Exam transportation cost			
log non-science jinshi share	-0.00125***	-0.00175***	-0.112**	-0.0987	-0.00674**	-0.203***	-0.369***
	(7.80e-05)	(0.000110)	(0.0572)	(0.0826)	(0.00283)	(0.0457)	(0.0936)
Province FE	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y
First-stage F statistic				11.042			
Observations	272	272	272	272	272	272	272
R-squared	0.783	0.786	0.895	0.843	0.707	0.332	0.548
	(15)	(16)	(17)	(18)	(19)	(20)	(21)
	log scientist den., Ming	log scientist den., Qing	log pop den.	log school, 1900	Urbanization rate	log charitable org., 1840	log Confucianists
				IV: Weather shocks			
log non-science jinshi share	-0.000704***	-0.00104***	-0.227***	-0.239*	-0.0107**	-0.341***	-0.589**
	(0.000154)	(0.000218)	(0.0665)	(0.123)	(0.00441)	(0.0655)	(0.281)
Province FE	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y
First-stage F statistic				31.167			
Observations	272	272	272	272	272	272	272
R-squared	0.745	0.756	0.874	0.832	0.659	0.227	0.522

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Such facts can be explained by the mechanism that keju fostered the accumulation of human capital (to be elaborated later in Section 6.5.1) and the formation of an open-minded and inclusive culture (to be elaborated in Section 6.5.2), which both gave rise to more revolutionists and political activists who joined KMT and/or CCP. For example, Song Jiaoren, a shengyuan of keju, later became a KMT member and a political leader of RoC. Chen Duxiu, a jinshi, and Li Dazhao, a Gongsheng of keju, later founded the Chinese Communist Party. Therefore, keju incubated the RoC and later the PRC after the downfall of the Qing dynasty.

Table 5: The Rise of KMT and Republic of China

	(1)	(2)	(3)	(4)	(5)
	KMT members	CCP members	New firms	Japan overseas	Newspapers
			IV: Distance to printing material		
log jinshi density	1.767***	0.453	0.511***	3.409**	9.053**
	(0.473)	(0.302)	(0.135)	(1.708)	(3.947)
First-stage F statistic			115.9		
Province FE	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y
Observations	272	272	272	272	272
R-squared	0.123	0.261	0.725	0.293	0.886
	(6)	(7)	(8)	(9)	(10)
	KMT members	CCP members	New firms	Japan overseas	Newspapers
			IVs: Weather shocks		
log jinshi density	0.645	0.692**	0.317**	2.243	2.533
	(0.553)	(0.293)	(0.143)	(1.580)	(1.682)
First-stage F statistic			17.852		
Province FE	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y
Observations	272	272	272	272	272
R-squared	0.206	0.245	0.737	0.303	0.889
	(11)	(12)	(13)	(14)	(15)
	KMT members	CCP members	New firms	Japan overseas	Newspapers
			IVs: Exam transportation costs		
log jinshi density	1.051	1.668**	1.024**	11.04***	11.69***
	(0.845)	(0.788)	(0.489)	(3.865)	(3.948)
First-stage F statistic			17.100		
Province FE	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y
Observations	272	272	272	272	272
R-squared	0.181	-0.013	0.618	-0.361	0.875

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Next, we estimate the time-varying effects of the keju exam. We first focus on the outcome of human capital, measured by educational attainments in the Census data. Table 6 reports the results. Jinshi density is relatively weakly associated with the educational attainments of the cohort of 1912-1937 and 1938-1949, the former of which is the RoC era before the start of the

Anti-Japanese war, and the latter of which is after the Anti-Japanese war. On the contrary, the positive effects are more salient for cohort 1977-1985, which is the PRC era after the economic reform and opening up initiated by Deng Xiaoping. Thus, the historical legacy of keju plays a more prominent role in economic development in contemporary China, especially when efficient institutions have been established.

Table 7 further corroborates this finding. We estimate the effects of jinshi density on business creation and innovation in different periods of the PRC era, and the positive effects are most salient for the 1993-2001 period when the central role of the market economy was supported by the Southern Tour of Deng Xiaoping. We further divide the full sample into two subsamples, in which the marketization index is higher or lower than the sample median. Table 8 suggests that the positive effects of jinshi density on business creation and innovation are more salient where the level of marketization is high. Such a result also supports the complementary role of keju and modern institutions.

6.4 Heterogeneity

In this section, we examine the heterogeneity behind the baseline results. We first explore ownership heterogeneity, i.e. state-owned or private. The results are presented in Table A7. The coefficients on the number of patent applications, R&D expenditure, and the number of new entrants are larger for private firms. These results are consistent with the observation that private firms are more profit-oriented and are not subject to soft budget constraints (Lin and Tan, 1999). Second, we explore the heterogeneity in firm size according to whether their paid-in capital belongs to the top 10% (large), top 10-50% (medium), or bottom 50% (small) percentile of the size distribution. The results in Table A8 indicate that the effects of keju are largest for small firms. Finally, we look at sectoral heterogeneity and classify the firms into three sectors: agriculture, industry, and service. The results reported in Table A9 indicate that the effects for the service sector are the largest. This might be interpreted to suggest that the service sector needs more human capital to innovate, which is consistent with the main channel to be examined below.

6.5 Three historical legacies

In this section, we argue that when keju no longer misallocates talents, it leaves modern and contemporary China with three historical legacies: human capital, culture, and institutions. They all play an important role in the growth miracle of contemporary China.

Table 6: Time-varying effects of keju on human capital accumulation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: People's Republic of China									
	Share of college graduates			Share of high school graduates			Share of junior high school graduates		
	1949-1965	1966-1976	1977-1985	1949-1965	1966-1976	1977-1985	1949-1965	1966-1976	1977-1985
	IV: Distance to printing materials								
log jinshi density	0.0347***	0.0468***	0.0764***	0.0732***	0.0753***	0.0958***	0.0531***	0.0370**	0.0207
	(0.00795)	(0.0102)	(0.0116)	(0.0199)	(0.0164)	(0.0174)	(0.0193)	(0.0164)	(0.0243)
First-stage F statistic					115.9				
Province FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.447	0.459	0.504	0.581	0.563	0.583	0.773	0.834	0.812
Panel B: Republic of China									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Share of college graduates			Share of high school graduates			Share of junior high school graduates		
	1912-1948	1912-1937	1938-1949	1912-1948	1912-1937	1938-1949	1912-1948	1912-1937	1938-1949
	IV: Distance to printing materials								
log jinshi density	0.0337***	0.0277***	0.0375***	0.0567***	0.0456***	0.0642***	0.0705***	0.0631***	0.0718***
	(0.00755)	(0.00628)	(0.00871)	(0.0136)	(0.0107)	(0.0156)	(0.0154)	(0.0143)	(0.0152)
First-stage F statistic					115.9				
Province FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.435	0.394	0.447	0.556	0.484	0.581	0.710	0.551	0.763

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table 7: Time-varying effects of keju on innovation and business creation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	log(Patent)	log(Firms) 2002-2020	log(Capital)	log(Patent)	log(Firms) 1993-2001	log(Capital)	log(Patent)	log(Firms) 1985-1992	log(Capital)
					IV: Distance to printing materials				
log jinshi density	1.374**	0.891*	2.217**	1.154***	0.227	0.479	0.594***	0.163	0.160
	(0.644)	(0.531)	(1.100)	(0.241)	(0.278)	(0.483)	(0.151)	(0.117)	(0.322)
Province FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.131	0.169	0.156	0.200	0.147	0.132	0.267	0.234	0.121

	(10)	(11)	(12)	(13)
	log(Firms) 1978-1984	log(Capital)	log(Firms) 1949-1977	log(Capital)
	IV: Distance to printing materials			
log jinshi density	0.0397	0.0330	0.0272***	0.0486
	(0.0307)	(0.217)	(0.00537)	(0.131)
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	272	272	272	272
R-squared	0.241	0.196	0.414	0.087

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table 8: The role of economic reform and opening up

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	log(Patents)		log(R&D)		log(Entrants, num)		log(Entrants, cap)	
	IV: Distance to printing materials							
	High	Low	High	Low	High	Low	High	Low
log jinshi density	1.259***	0.575	1.154***	0.411	0.832***	0.399	0.643**	0.120
	(0.162)	(0.376)	(0.237)	(0.518)	(0.188)	(0.352)	(0.246)	(0.426)
p-value	0.023		0.031		0.015		0.044	
Province FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
Observations	132	140	132	140	132	140	132	140
R-squared	0.782	0.603	0.765	0.494	0.717	0.671	0.603	0.656

Notes: The total sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. "High" stands for provinces with a level of marketization higher than the median. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

6.5.1 The Role of Human Capital

As in Chen et al. (2020), a salient role of keju in shaping contemporary China's economy is that it facilitates the accumulation of contemporaneous human capital. In turn, human capital is also an important ingredient for innovation, business creation, and economic development. This is a well-established argument in the literature (Waldinger (2016); Akcigit et al. (2020); Biasi and Ma (2022)). To establish the argument that keju explains the growth miracle of contemporary China via human capital accumulation, we first estimate the effects of keju on contemporaneous human capital, replicating the results of Chen et al. (2020). We report the results in Table 9. The average years of education and the share of the population that finishes college are strongly and positively correlated with the level of success in the keju exam. For example, increasing jinshi density by 1% leads to an increase in average years of education by 0.103%, and an increase in college graduate share by 0.731%.

Next, we turn to estimating the contemporaneous effects of human capital on innovation, business creation, and firm performance. Using average years of education and the share of residents who have finished high school as the main independent variable, and using the same instrumental variable for the contemporaneous level of human capital (distance to the nearest place that produces printing ingredients),[20] we find that contemporaneous human capital also has both statistically and economically significant effects on innovation, business creation, and firm outcomes (Table A10). Thus, we strengthen our argument that human capital is an important factor for innovation and firms' success, both of which lead to the growth miracle of contemporary China. In addition, Table B7 indicates that after controlling for human capital, the role of keju is no longer salient. Thus, human capital is an important pathway through which the positive effects of keju on economic growth are at play.

6.5.2 The Role of Culture

In this section, we document the effects of keju on contemporaneous measures of culture. We use China Family Panel Survey (CFPS) data to measure culture.[21] To be more specific, we use four kinds of measures. All these measures correspond to personality or personal characteristics, which are an outcome that is shaped by the culture.[22] First, CFPS provides survey questions regarding risk attitude. This is an important measure since the ability to deal with risks and uncertainties is essential for innovation and entrepreneurship. Second, CFPS provides survey

[20] Since the distance to the production site of printing materials still provides exogenous variations, this instrumental variable strategy is still valid. The relevance condition also holds due to a high F-statistic.

[21] A detailed description of the data is provided in Appendix C.2.

[22] Kluckhohn and Mowrer (1944) and Benet-Martínez and Oishi (2008) provide arguments on the close relationship between personalities and cultures. They both argue that personal characteristics are an outcome of the culture of the society.

Table 9: Effects of keju on modern-day human capital

	(1)	(2)	(3)	(4)	(5)
	log years of education	log illiterate share	log below middle school share	log high school share	log above college share
			IV: Distance to printing materials		
log jinshi density	0.103***	-0.344***	-0.131***	0.180***	0.731***
	(0.0101)	(0.0523)	(0.0184)	(0.0320)	(0.0908)
Province FE	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y
Observations	272	272	272	272	272
R-squared	0.701	0.710	0.598	0.671	0.554

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

questions on children's personality, which is an important outcome of culture and parental beliefs and investments. Third, CFPS provides data on the level of interpersonal trust. In a society with a high level of trust, economic activities run more smoothly and then leading to better economic outcomes. Finally, CFPS provides measures of how survey respondents value education and knowledge. This is also a crucial measure of culture since it is conducive to the selection of high-skilled occupations including scientists and entrepreneurs.

We report the results in Table 10. We use individual-level data but the same instrumental variable estimation strategy. The details of the sample and variable construction can be found in the table notes and Appendix C. In Panel A, we estimate the effects of keju on risk preferences. Using different measures, we consistently document that in cities with a higher level of keju success, people prefer risks more. In Panel B, we estimate the effects of keju on children's personalities. We find that keju makes children more patient, more careful, more curious, more sociable, more helpful, and more self-reliant. All these characteristics are beneficial for innovation and entrepreneurship. In Panel C, we assess the impacts of keju on modern-day trust levels. In cities with a higher level of keju success, people have a higher level of interpersonal trust, toward parents, neighbors, Americans, strangers, local cadre, and doctors. Such a social atmosphere may facilitate economic and social activities including innovation and entrepreneurship. Finally, in Panel D, we evaluate the effects of keju on social values. We find that keju increases educational expenditures and expenditures on textbooks, and makes people value education more. All four panels provide consistent evidence that keju fosters cultures conducive to innovation and entrepreneurship that may explain contemporary China's growth miracle.

Second, we test whether keju undermines people's creativity, by forcing participants to answer exam questions in a rigid fashion (Cho, 2007; Zhu and Chang, 2019). We use World Value Survey (WVS) data to answer this question. The WVS data has information on whether survey respondents may evaluate themselves as creative, whether they engage in creative tasks, and respondents' attitudes toward science. In Table B8, we present the estimation results. Since the WVS data only includes home province information for each respondent, we use the province average jinshi density as the main independent variable and employ a logit estimation strategy.[23] In column (1) of Table B8, where the dependent variable is the respondent's self-evaluation of their creativity, the coefficient on the provincial jinshi density is positive and statistically significant. Thus, the keju system actually fosters people's creativity. In columns (2) and (3), the independent variables become the respondent's attitudes towards science: basically, whether they think science benefits our lives. The coefficients, again, are positive, suggesting that in regions with higher exposure to keju's influence, people are more pro-science. Finally, in

[23] We do not exploit a similar instrumental variable approach since the distance to printing materials no longer works as a valid IV for provinces.

Table 10: Effects of keju on modern-day culture

Panel A: Effects on risk attitude						
	(1)	(2)	(3)	(4)	(5)	
	1(Risky 1)	1(Risky 2)	1(Risky 3)	1(Risky 4)	1(Risky 5)	
	IV: Distance to printing materials					
log jinshi density	0.130**	0.130**	0.121*	0.138*	0.138*	
	(0.0584)	(0.0583)	(0.0627)	(0.0719)	(0.0751)	
Province FE	Y	Y	Y	Y	Y	
Controls	Y	Y	Y	Y	Y	
Observations	7,276	7,276	7,276	7,276	7,276	
R-squared	0.093	0.118	0.148	0.340	0.398	

Panel B: Effects on children personality						
	(1)	(2)	(3)	(4)	(5)	(6)
	1(Happy)	1(Patient)	1(Careful)	1(Curious)	1(Discreet)	1(Sociable)
	IV: Distance to printing materials					
log jinshi density	0.00506	0.103*	0.101*	0.0978**	0.0993	0.0928*
	(0.0162)	(0.0512)	(0.0584)	(0.0436)	(0.0613)	(0.0470)
Province FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	7,276	7,276	7,276	7,276	7,276	7,276
R-squared	0.005	0.068	0.069	0.058	0.076	0.056
	(7)	(8)	(9)	(10)	(11)	(12)
	1(Tolerant)	1(Helpful)	1(Conforming)	1(Tough)	1(Admirable)	1(Self-reliant)
	IV: Distance to printing materials					
log jinshi density	0.113**	0.0983*	0.00536	0.0987	-0.00404	0.106*
	(0.0489)	(0.0539)	(0.0182)	(0.0600)	(0.0178)	(0.0574)
Province FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	7,276	7,276	7,276	7,276	7,276	7,276
R-squared	0.075	0.057	0.006	0.085	0.006	0.065

Panel C: Effects on interpersonal trust level						
	(1)	(2)	(3)	(4)	(5)	(6)
	Trust toward different social groups					
	Parents	Neighbors	American	Strangers	Local cadre	Doctors
	IV: Distance to printing materials					
log jinshi density	0.139***	0.442***	0.595***	0.538***	0.471***	0.355**
	(0.0465)	(0.104)	(0.166)	(0.119)	(0.127)	(0.126)
Province FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	86,395	86,395	86,395	86,395	86,395	86,395
R-squared	0.020	0.021	0.040	0.030	0.022	0.021

Panel D: Effects on social values				
	(1)	(2)	(3)	(4)
	log(1+Edu. Exp.)	log(1+Textbook exp.)	1(Value edu.)	1(Edu. is impt. social issue)
	IV: Distance to printing materials			
log jinshi density	0.121***	0.0638**	0.0113*	0.359***
	(0.0334)	(0.0227)	(0.00620)	(0.105)
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	25,562	25,562	1,441	24,682
R-squared	0.004	0.004	0.019	0.008

Notes: The sample is constructed using the China Family Panel Survey (CFPS) data. 1(Risky 1)-1(Risky 5) are indicators equal to 1 if the respondent prefers risks. The dependent variables in Panel B are the evaluation of the children's parents. In Panel C, the higher the trust score, the higher the level of trust of the respondent toward certain groups. "Edu. Exp." stands for educational expenditures. "Textbook exp." stands for textbook expenditures. "Value edu." stands for "valuing education." "1(Edu. is impt. social issue)" stands for "agreeing that education is an important social issue." The details of the variable construction are provided in the Appendix. IV: Distance to printing materials estimation is employed. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

column (4), the dependent variable becomes whether the respondent engages in creative tasks. The coefficient on provincial jinshi density is positive and statistically significant, also implying that keju enhances people's creativity.

Third, we test whether keju exposure fosters entrepreneurship.[24] We use the density of CEOs in listed firms and legal representatives of registered firms as the dependent variable and estimate the instrumental variable specification. According to the results in Table B9, increasing jinshi density by 1% leads to an increase in CEO density by 1.421%, and legal representative density by 0.764%. Thus, keju exposure indeed fosters entrepreneurship.

Finally, we test whether cultures may impact innovation and business creation in contemporary China. Using the same instrumental variable estimation approach and city-level cross-sectional data,[25] we find that, according to Table A11, the mean level of risk preference, the mean level of trust, the mean level of attention to education, and the mean level of patience, all calculated from the CFPS data, have positive effects on patent applications, R&D expenditures, firm entry, and firm performance. The effects are also statistically and economically significant. Therefore, keju shapes a productive and innovative culture that may explain contemporary China's growth miracle. In addition, Table B10 indicates that after controlling for cultures, the role of keju is no longer salient. Thus, cultures are an important pathway through which the positive effects of keju on economic growth are at play. A final note is that culture also fosters human capital accumulation, and, its effects depend on the level of human capital. Therefore, it is infeasible to separately estimate the contributions of human capital and culture.

6.5.3 The Role of Institutions

The final role of keju in explaining the growth miracle of contemporary China is that keju facilitates the establishment of a market-oriented institution that is friendly to economic activities including innovation and entrepreneurship.[26] First of all, an efficient institution relies on the level of human capital, culture, and other economic conditions. Thus, keju can facilitate institutional building due to its role in accumulating human capital and fostering a productive culture that both provide foundations for efficient institutions. Such an argument is also supported by the complementary role of institutions, human capital, and culture (Acemoglu et al. (2014)). Our empirical analysis then starts from the fact that in cities with a higher level of keju success, the city officials born in that city are more educated and are more likely to major in economics, science, and technology. This is documented by the results in Table A12, in which we use the same instrumental variable estimation strategy. A better-educated leader will implement

[24] Chakraborty et al. (2016) argue that entrepreneurship depends on the culture.

[25] Since the distance to the production site of printing materials still provides exogenous variations, this instrumental variable strategy is still valid.

[26] We provide positive correlations between keju and contemporary institutions in Figure A1.

more efficient policies and establish a better-established institution that facilitates innovation and entrepreneurship. This is reflected in the city government's work reports (GWR), which may contain policy goals to strengthen the market order, create a healthy business environment, establish a mature financial market, and combat corruption.[27] In Table 11, we find that keju success increases the share of keywords related to (1) market order; (2) business environment; (3) judicial quality; (4) financial market; and (5) combating corruption. For instance, increasing jinshi density by 1% raises the share of keywords related to market order in GWR by 2.16 standard deviations. Therefore, keju fosters a better institution for innovation and entrepreneurship. Moreover, using CFPS data, we find that keju reduces the likelihood of feeling treated unfairly by the local government. This strengthens our argument that keju improves the quality of institutions. A possible explanation that institutional quality is positively related to keju is that the role of institutions is complementary to that of human capital and culture. In other words, it is easier to establish an effective institution given a higher level of human capital and a better culture. The details of the sample and variable construction can be found in the table notes and Appendix C.

Similar to the above analysis, we also estimate the effects of measures of institution quality on innovation and firm performance. We present the results in Table A13. Using the same instrumental variable strategy, we document that the share of keywords related to market order or business environment in government work reports has a strong positive effect on patent applications, R&D expenditures, firm entry, and firm performance.[28] The mean level of being unfairly treated has a strong and negative effect on these outcomes. Therefore, the quality of institutions is a strong indicator that can explain the growth miracle of contemporary China. In addition, Table B11 indicates that after controlling for institutions, the role of keju is no longer salient. Thus, institutions are an important pathway through which the positive effects of keju on economic growth are at play. Also, a final note as before is that institutions also foster human capital accumulation and cultural development, and, its effects depend on the level of human capital and the nature of culture (Acemoglu et al., 2014). Therefore, it is infeasible to separately estimate the contributions of human capital, culture, and institutions.

6.6 Alternative Explanations

In this section, we test whether alternative explanations hold. We focus on three alternative explanations: (1) Economic geography, (2) Environmental conditions, and (3) Confucianism and thought controls.

[27]The implicit assumption here is that GWR reflects policies that shape institutions.

[28]Since the distance to the production site of printing materials still provides exogenous variations, this instrumental variable strategy is still valid.

Table 11: Effects of keju on modern-day institutions

Panel A: Effects on social atmosphere							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Reasons of feeling unfair						
	1(Income diff.)	1(Hukou)	1(Gender)	1(Gov.)	1(Conflict with gov.)	1(Procrastinate gov.)	1(Gov. unreasonable charging)
	IV: Distance to printing materials						
log jinshi density	-0.0415***	-0.0113	-0.00453	-0.0275***	-0.00730	-0.0365***	-0.0145**
	(0.0101)	(0.00722)	(0.00373)	(0.00803)	(0.00655)	(0.0110)	(0.00597)
Province FE	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y
Observations	29,039	29,039	29,039	29,039	29,039	29,039	29,039
R-squared	0.023	0.014	0.014	0.022	0.005	0.015	0.008

Panel B: Effects on gov. work report					
	(1)	(2)	(3)	(4)	(5)
	Market order	Busi. Env.	Judicial	Financial mkt.	Corruption
	IV: Distance to printing materials				
log jinshi density	0.0797***	0.115***	0.145***	0.0991***	0.0704***
	(0.00341)	(0.00311)	(0.00408)	(0.00467)	(0.00174)
Province FE	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y
Observations	272	272	272	272	272
R-squared	0.946	0.960	0.964	0.937	0.947

Notes: In Panel A the sample is constructed using the China Family Panel Survey (CFPS) data. The details of the variable construction are provided in the Appendix. In Panel B, the sample covers 272 prefecture cities in 31 provinces. IV: Distance to printing materials estimation is employed. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Economic Geography: We first test whether the location of the focal city matters for business creation and innovation in contemporary China, controlling for jinshi density. Columns (1) through (4) in Table 12 suggest that the various distances of the focal city to the commercial center, silk centers, tea centers, large cities, and the capital Beijing have jointly significant effects on outcomes of interest. Thus, besides the keju exam that contributes to the growth of contemporary China, economic geography also matters.

Environmental Conditions: We second examine whether environmental conditions matter for economic development, controlling for jinshi density. We use agricultural, rice, wheat, economic crops, maize, sweet potato suitability, and droughts as a measure of environmental conditions. Columns (5) through (8) in Table 12 indicate that these variables are jointly statistically significant. Thus, besides the keju exam, environmental conditions also matter for contemporary economic development.

Confucianism and Thought Controls: Finally, we test whether Confucianism (also a measure of thought controls) matters for economic development, after controlling for jinshi density. Surprisingly, columns (9) through (12) in Table 12 suggest that Confucianism plays a positive role in contemporary development conditional on jinshi density. Thus, a related explanation, or conjecture, is that Confucianism also contributes to human capital, culture, and institutions which are the historical legacies of keju. This is consistent with the findings of Dong and Zhang (2024).[29]

7 Conclusion

In this paper, we examine the effects of China's imperial examination system (keju), a long-lived institution in Imperial China, on modern-day innovation, business creation, and firm performance. Using variation in the density of jinshi (the highest exam qualification) and three instrumental variable estimation strategies, we find that keju significantly facilitates innovation and firm entry, and improves firm performance. Keju played an important role in various periods of historical, modern, and contemporary China, but its effects were most pronounced after the economic reform and opening up of the PRC era. As for mechanisms, we find that human capital, culture, and institutions are key factors, whose historical root is China's imperial examination system (keju).

Our analysis sheds light on a long-lasting puzzle and one of the most prominent phenomena in the developing world: Why China was not the origin of the Industrial Revolution but experienced a splendid growth miracle in the past four decades? We provide a unified narrative

[29]Dong and Zhang (2024) argue that Confucianism contributed to the accumulation of human capital and the rise of modern science in China, but Confucian values did not.

Table 12: Testing alternative hypotheses

	(1)	(2)	(3)	(4)
	log(Patents)	log(R&D)	log(Entrants, num)	log(Entrants, cap)
		IV: Distance to printing materials		
log jinshi density	1.026***	0.956***	0.672***	0.510***
	(0.139)	(0.214)	(0.139)	(0.164)
log distance to commercial center	0.105	0.304	0.0760	0.202
	(0.263)	(0.301)	(0.188)	(0.305)
log distance to silk centers	0.310	0.394	0.341***	0.733***
	(0.212)	(0.263)	(0.126)	(0.228)
log distance to tea centers	0.114	0.141	0.0193	-0.395
	(0.247)	(0.187)	(0.162)	(0.285)
log distance to large cities	0.0556	0.0967	0.0544	0.0761
	(0.0753)	(0.0812)	(0.0622)	(0.0801)
log distance to Beijing	0.210	0.346	-0.196	0.00577
	(0.300)	(0.639)	(0.272)	(0.495)
log distance to provincial capital	-0.186	-0.291	-0.114	-0.300**
	(0.187)	(0.181)	(0.105)	(0.127)
log distance to river	0.0317	0.0488	-0.0148	0.000618
	(0.0629)	(0.0796)	(0.0482)	(0.0978)
log distance to coast	0.109	0.195	0.0567	0.187
	(0.140)	(0.227)	(0.0865)	(0.118)
F-test p-value	0.0000***	0.0000***	0.0000***	0.0000***
First-stage F statistic			115.9	
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	272	272	272	272
R-squared	0.747	0.667	0.694	0.665

	(5)	(6)	(7)	(8)
	log(Patents)	log(R&D)	log(Entrants, num)	log(Entrants, cap)
		IV: Distance to printing materials		
log jinshi density	1.077***	0.962***	0.718***	0.577***
	(0.129)	(0.180)	(0.115)	(0.150)
Agricultural suitability	0.0904	0.265*	0.0670	0.129
	(0.156)	(0.151)	(0.105)	(0.262)
Rice suitability	-0.0295**	-0.0438***	-0.0325***	-0.0359**
	(0.0130)	(0.0146)	(0.00877)	(0.0157)
Wheat suitability	-0.00299	-0.0195	0.0105	-0.00329
	(0.0195)	(0.0226)	(0.0125)	(0.0188)
Economic crops suitability	0.0565	0.0319	0.0158	0.0746
	(0.0368)	(0.0382)	(0.0237)	(0.0467)
Maize suitability	-0.00866	0.0221	-0.00428	-0.00876
	(0.0174)	(0.0244)	(0.0110)	(0.0207)
Sweet potato suitability	-0.00486	0.00102	0.0104	-0.00361
	(0.0188)	(0.0178)	(0.0115)	(0.0186)
Droughts	-0.627	-4.462*	-0.641	2.211
	(1.902)	(2.328)	(1.025)	(1.716)
Floods	-2.297	-0.263	-1.546	-3.107
	(3.248)	(4.249)	(2.121)	(3.948)
F-test p-value	0.0000***	0.0000***	0.0000***	0.0000***
First-stage F statistic			115.9	
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	272	272	272	272
R-squared	0.743	0.673	0.697	0.663

	(9)	(10)	(11)	(12)
	log(Patents)	log(R&D)	log(Entrants, num)	log(Entrants, cap)
		IV: Distance to printing materials		
log jinshi density	0.874***	0.770***	0.569***	0.347
	(0.199)	(0.264)	(0.181)	(0.241)
log Confucianists	0.266***	0.244***	0.151***	0.232***
	(0.0575)	(0.0613)	(0.0312)	(0.0519)
First-stage F statistic			115.9	
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	272	272	272	272
R-squared	0.771	0.679	0.715	0.672

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

that provides the answer. In historical periods, keju diverted top talents into the rigid examination and bureaucratic system, not innovative and productive activities. However, in modern and contemporary China where keju is no longer in effect, it provides three historical legacies: raising the contemporaneous level of human capital, shaping innovative and productive culture, and fostering efficient market-oriented institutions. These laid a solid foundation for the rapid economic and scientific development in the past four decades.

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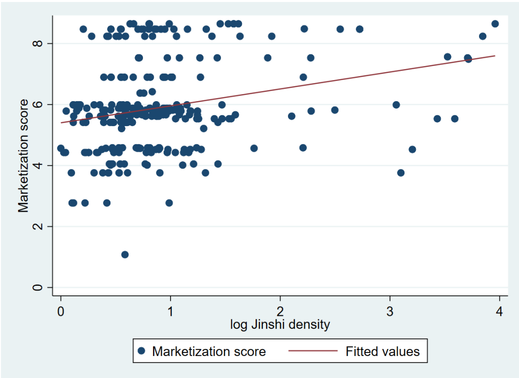
Online Appendix

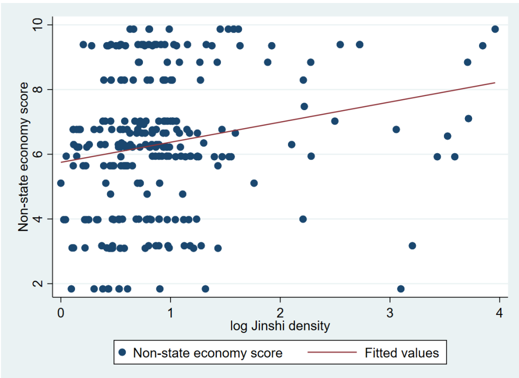
Appendix A Figures and Tables

Figure A1: Correlations of keju and institutions

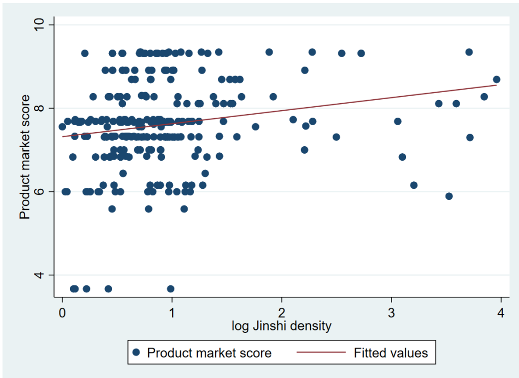


(a)

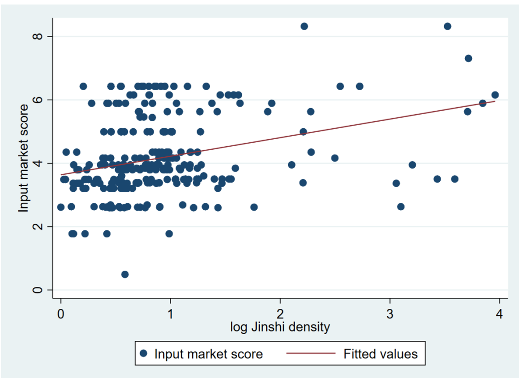
(b)



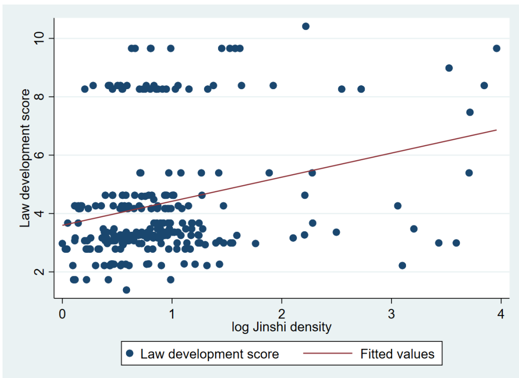
(c)



(d)



(e)



(f)

Notes: The measures of institutions are at the province level, and the data source is Fan et al. (2003).

Table A1: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
		Panel A: City-level data			
log jinshi density	272	0.917	0.702	0	3.959
log(Patent)	272	7.513	1.989	0	12.761
log(R&D)	272	14.029	2.122	0	19.389
log(Entrants, num)	272	6.860	1.140	3.258	10.038
log(Entrants, cap)	272	16.494	1.723	11.37	21.688
Avg. revenue/L	272	732.146	351.141	0.000	2917.853
Avg. profit/L	272	8.366	12.279	-3.383	166.919
Avg. export/L	272	33.499	50.512	0	320.924
log(Patent per firm)	272	-0.710	1.173	-4.868	1.891
log(R&D per firm)	272	5.806	1.372	-4.754	8.939
log science-related jinshi share	272	-4.020	1.830	-12.531	-1.471
GWR (market)	272	0.073	0.058	0.022	0.312
GWR (busi. env.)	272	0.109	0.087	0.050	0.481
GWR (judicial)	272	0.127	0.103	0.044	0.573
GWR (financial mkt.)	272	0.091	0.073	0.043	0.402
GWR (corruption)	272	0.067	0.050	0.002	0.283
		Panel B: Individual-level data			
1(Risky 1)	7,276	0.210	0.407	0	1
1(Risky 2)	7,276	0.172	0.377	0	1
1(Risky 3)	7,276	0.136	0.342	0	1
1(Risky 4)	7,276	0.062	0.242	0	1
1(Risky 5)	7,276	0.052	0.221	0	1
Trust (parents)	86,395	9.351	1.446	0	10
Trust (neighbors)	86,395	7.019	2.306	0	10
Trust (American)	86,395	3.505	3.451	0	10
Trust (Strangers)	86,395	3.075	3.177	0	10
Trust (local cadre)	86,395	5.678	2.863	0	10
Trust (doctor)	86,395	7.240	2.356	0	10
1(Patient)	7,276	0.271	0.445	0	1
1(Curious)	7,276	0.306	0.461	0	1
1(Discreet)	7,276	0.239	0.427	0	1
1(Sociable)	7,276	0.324	0.468	0	1
1(Tolerance)	7,276	0.252	0.434	0	1
1(Helpful)	7,276	0.305	0.460	0	1
1(Self-reliant)	7,276	0.276	0.447	0	1

Notes: "GWR" stands for government work report. 1(Risky 1) to 1(Risky 5) measures the risk attitudes of survey respondents. They equal to 1 if they are risk-loving.

Table A2: First-stage regression

	(1)	(2)	(3)	(4)	(5)	(6)
	log jinshi density			log non-science jinshi share		
	OLS					
log distance to bamboo and pine	-0.0850***			0.0871***		
	(0.0109)			(0.0301)		
log distance to first-level exam location		-0.151*			0.192**	
		(0.0831)			(0.0732)	
log distance to second-level exam location		-0.110			-0.106	
		(0.215)			(0.417)	
log distance to third-level exam location		-0.139			0.455**	
		(0.110)			(0.193)	
Number of droughts			-0.00908*			0.0203*
			(0.00495)			(0.00990)
Number of earthquakes			-0.00941*			0.0305***
			(0.00567)			(0.00863)
Province FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	272
R-squared	0.649	0.466	0.546	0.662	0.572	0.685

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table A3: Baseline without controls, OLS estimation

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
		OLS	
log jinshi density	1.223***	1.257***	0.674***
	(0.176)	(0.149)	(0.122)
Province FE	Y	Y	Y
Controls	N	N	N
Observations	272	272	272
R-squared	0.639	0.549	0.598

	(4)	(5)	(6)
	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L
		OLS	
log jinshi density	0.924***	188.9***	1.767**
	(0.139)	(32.71)	(0.759)
Province FE	Y	Y	Y
Controls	N	N	N
Observations	272	272	272
R-squared	0.530	0.396	0.781

	(7)	(8)	(9)
	Avg. export/L	log(Patents per firm)	log(R&D per firm)
		OLS	
log jinshi density	23.08***	0.517***	0.550***
	(7.956)	(0.0806)	(0.0632)
Province FE	Y	Y	Y
Controls	N	N	N
Observations	272	272	272
R-squared	0.514	0.641	0.458

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table A4: Baseline-OLS estimation with controls

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
		OLS	
log jinshi density	0.738***	0.768**	0.335**
	(0.232)	(0.280)	(0.156)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.724	0.634	0.665
	(4)	(5)	(6)
	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L
		OLS	
log jinshi density	0.629*	144.8**	0.897
	(0.364)	(58.80)	(1.577)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.634	0.385	0.784
	(7)	(8)	(9)
	Avg. export/L	log(Patents per firm)	log(R&D per firm)
		OLS	
log jinshi density	-0.420	0.395***	0.426**
	(9.232)	(0.112)	(0.178)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.541	0.722	0.532

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table A5: Correlations of distances

	(1)	(2)	(3)	(4)	(5)
	log distance to printing materials				
log distance to the coast	0.615				
	(0.780)				
log distance to Beijing		1.250			
		(1.837)			
log distance to provincial capital			0.862		
			(0.606)		
log distance to tea center				2.84e-06	
				(2.48e-06)	
log distance to silk center					1.89e-06
					(3.69e-06)
Province FE	Y	Y	Y	Y	Y
Controls	N	N	N	N	N
Observations	272	272	272	272	272
R-squared	0.581	0.580	0.586	0.582	0.580

Notes: The sample covers 272 prefecture cities in 31 provinces. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table A6: The downfall of Qing Dynasty

	(1)	(2)	(3)	(4)
	Revolutionists	Number of revolutions	Revolutionists	Number of revolutions
	IV: Distance to printing materials			
log jinshi density	3.237**	0.199***		
	(1.442)	(0.0702)		
log non-science jinshi			-3.161*	-0.195**
			(1.839)	(0.0975)
First-stage F statistic	115.9		25.835	
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	272	272	272	272
R-squared	0.204	0.192	0.088	0.071

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table A7: Ownership heterogeneity

	(1)	(2)	(3)	(4)
	log(Patents)		log(R&D)	
	SOE	Private	SOE	Private
	IV: Distance to printing materials			
log jinshi density	0.815***	1.142***	0.916***	1.250***
	(0.200)	(0.231)	(0.292)	(0.265)
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	272	272	272	272
R-squared	0.691	0.780	0.618	0.674

	(5)	(6)	(7)	(8)
	log(Entrants, num)		log(Entrants, cap)	
	SOE	Private	SOE	Private
	IV: Distance to printing materials			
log jinshi density	0.529***	0.789***	0.456*	0.641**
	(0.151)	(0.183)	(0.261)	(0.254)
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	272	272	272	272
R-squared	0.641	0.690	0.565	0.676

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table A8: Size heterogeneity

	(1)	(2)	(3)	(4)	(5)	(6)
	log(Patents)			log(R&D)		
	Large	Medium	Small	Large	Medium	Small
	IV: Distance to printing materials					
log jinshi density	0.924***	0.931***	1.110***	0.945***	0.876***	1.195***
	(0.205)	(0.178)	(0.193)	(0.264)	(0.201)	(0.306)
Province FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	270
R-squared	0.712	0.732	0.682	0.649	0.711	0.510

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table A9: Sectoral heterogeneity

	(1)	(2)	(3)	(4)	(5)	(6)
	log(Patents)			log(R&D)		
	Agriculture	Industry	Service	Agriculture	Industry	Service
	IV: Distance to printing materials					
log jinshi density	0.943***	0.891***	1.579***	2.376***	0.808***	1.796***
	(0.329)	(0.196)	(0.378)	(0.672)	(0.271)	(0.424)
Province FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	269
R-squared	0.362	0.723	0.582	0.264	0.633	0.494

	(7)	(8)	(9)	(10)	(11)	(12)
	log(Entrants, num)			log(Entrants, cap)		
	Agriculture	Industry	Service	Agriculture	Industry	Service
	IV: Distance to printing materials					
log jinshi density	0.278*	0.448***	0.729***	0.598	0.424*	0.678***
	(0.154)	(0.131)	(0.179)	(0.447)	(0.238)	(0.262)
Province FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	272
R-squared	0.557	0.687	0.665	0.351	0.490	0.638

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table A10: Contemporaneous effects of human capital

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	log(Patents)	log(R&D)	log(Entrants, num)	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L	Avg. export/L	log(Patents per firm)	log(R&D per firm)
	IV: Distance to printing materials								
log years of education	11.69***	10.35***	7.484***	5.316**	2,077***	35.98*	251.0***	4.346***	3.004*
	(1.743)	(2.215)	(1.532)	(2.291)	(788.9)	(19.51)	(89.08)	(1.385)	(1.607)
Province FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.782	0.700	0.722	0.681	0.436	0.774	0.548	0.748	0.560

	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
	log(Patents)	log(R&D)	log(Entrants, num)	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L	Avg. export/L	log(Patents per firm)	log(R&D per firm)
	IV: Distance to printing materials								
log high school share	7.508***	6.646***	7.508***	4.808***	3.415**	1,334**	23.11*	161.2**	2.792**
	(1.457)	(1.472)	(1.457)	(0.868)	(1.456)	(607.8)	(13.72)	(77.65)	(1.095)
Province FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.598	0.571	0.598	0.441	0.635	0.259	0.728	0.387	0.694

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table A11: Contemporaneous effects of culture

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	log(Patents)	log(R&D)	log(Entrants, num)	Avg. revenue/L	log(Patents)	log(R&D)	log(Entrants, num)	Avg. revenue/L
				IV: Distance to printing materials				
Mean risk attitude	9.450**	8.498*	6.157*	2,235***				
	(4.415)	(4.511)	(3.142)	(723.7)				
Mean trust level					2.046***	1.883**	1.360**	506.9***
					(0.765)	(0.827)	(0.539)	(139.9)
Province FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
Observations	105	105	105	105	105	105	105	105
R-squared	0.597	0.584	0.560	0.485	0.520	0.501	0.492	0.329

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	log(Patents)	log(R&D)	log(Entrants, num)	Avg. revenue/L	log(Patents)	log(R&D)	log(Entrants, num)	Avg. revenue/L
				IV: Distance to printing materials				
Mean education attention	5.892*	5.421	3.918*	1,460				
	(3.431)	(3.577)	(2.236)	(978.1)				
Mean patience					12.11*	10.89	7.890	2,864**
					(7.064)	(6.797)	(4.853)	(1,180)
Province FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y
Observations	105	105	105	105	105	105	105	105
R-squared	0.377	0.174	0.372	0.545	0.448	0.450	0.456	0.355

Notes: The sample covers 105 prefecture cities in 31 provinces (105 because CFPS's data coverage is limited). Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table A12: Effects on city officials' educational attainments

	(1)	(2)	(3)	(4)
	1(College)	1(Grad school)	1(Science/Engineering)	1(Econ)
		IV: Distance to printing materials		
log jinshi density	0.0632**	0.154*	0.0511*	0.0255*
	(0.0299)	(0.0876)	(0.0299)	(0.0127)
Province FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	12,580	12,580	12,580	12,580
R-squared	0.059	0.129	0.038	0.027

Notes: The sample covers 12,580 city-year observations (city mayors and city Party Secretaries) in 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table A13: Contemporaneous effects of institutions

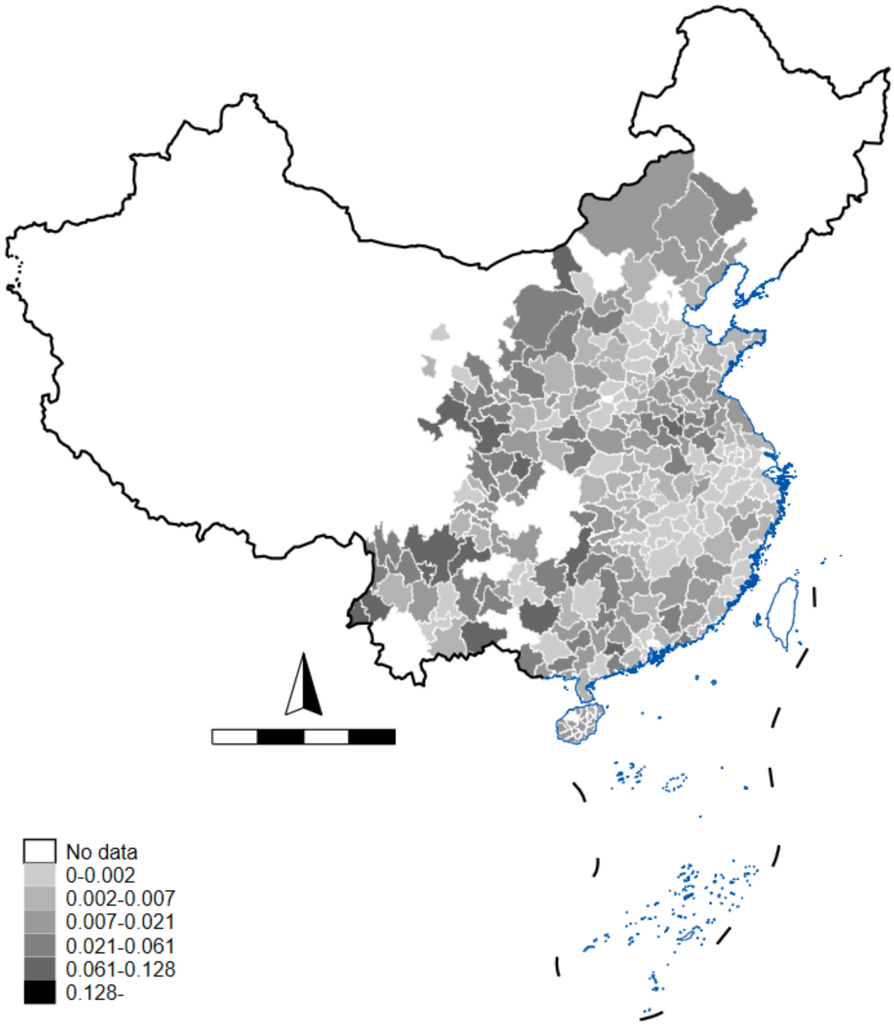
	(1)	(2)	(3)	(4)
	log(Patents)	log(R&D)	log(Entrants, num)	Avg. revenue/L
		IV: Distance to printing materials		
Market order (GWR)	12.51***	11.07***	8.010***	2,223***
	(2.137)	(3.075)	(1.974)	(796.3)
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	272	272	272	272
R-squared	0.730	0.648	0.668	0.444
	(5)	(6)	(7)	(8)
	log(Patents)	log(R&D)	log(Entrants, num)	Avg. revenue/L
		IV: Distance to printing materials		
Busi. Env. (GWR)	8.658***	7.664***	5.544***	1,539**
	(1.429)	(2.104)	(1.436)	(604.5)
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	272	272	272	272
R-squared	0.723	0.645	0.664	0.430
	(9)	(10)	(11)	(12)
	log(Patents)	log(R&D)	log(Entrants, num)	Avg. revenue/L
		IV: Distance to printing materials		
Unfair (gov)	-51.45**	-46.27***	-33.52***	-12,169**
	(20.89)	(17.61)	(11.48)	(5,143)
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	105	105	105	105
R-squared	0.692	0.384	0.731	0.604

Notes: The sample covers 272(105) prefecture cities in 31 provinces (105 because CFPS's data coverage is limited). Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Online appendix not for publication, available by request

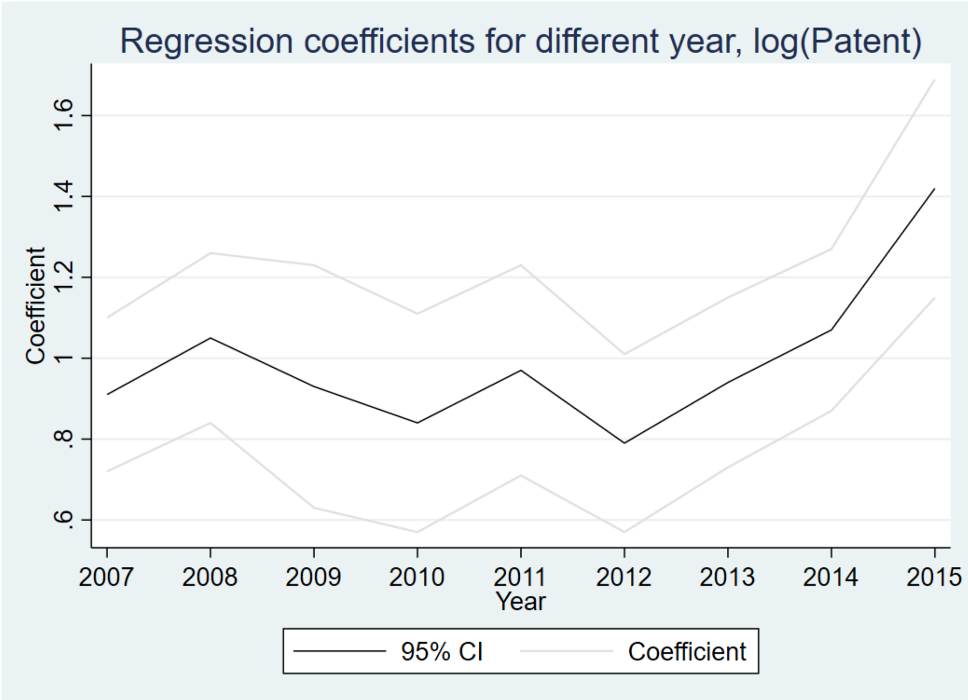
Appendix B Figures and Tables

Figure B1: Spatial distribution of science-related jinshi share



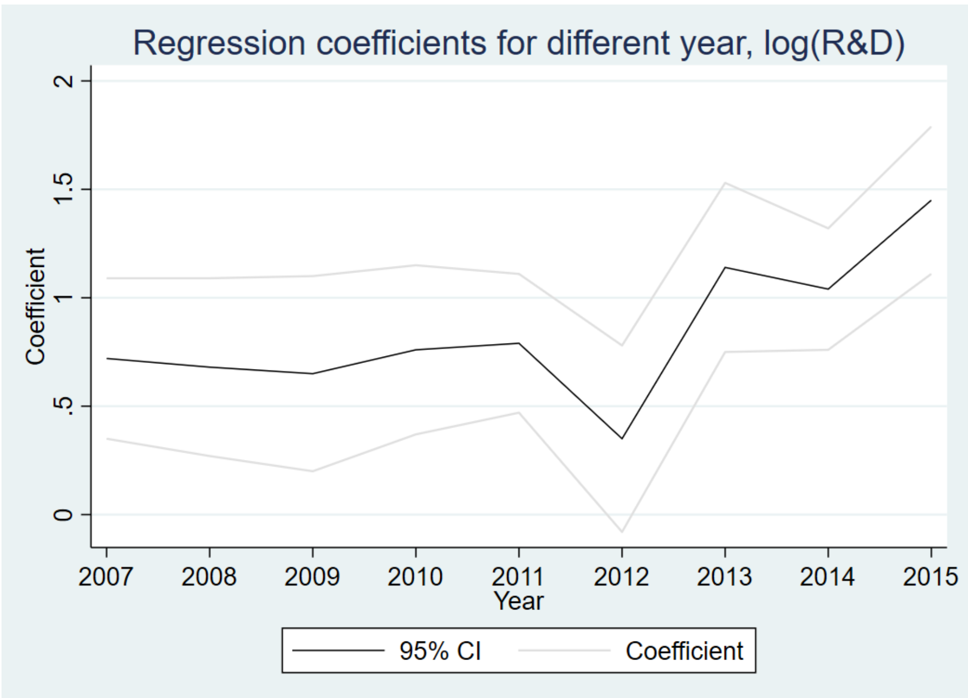
Notes: The figure plots the spatial distribution of science-related jinshi share, calculated as the ratio of science-related jinshi over total jinshi in a certain prefecture city.

Figure B2: Time varying effects of keju on patent applications



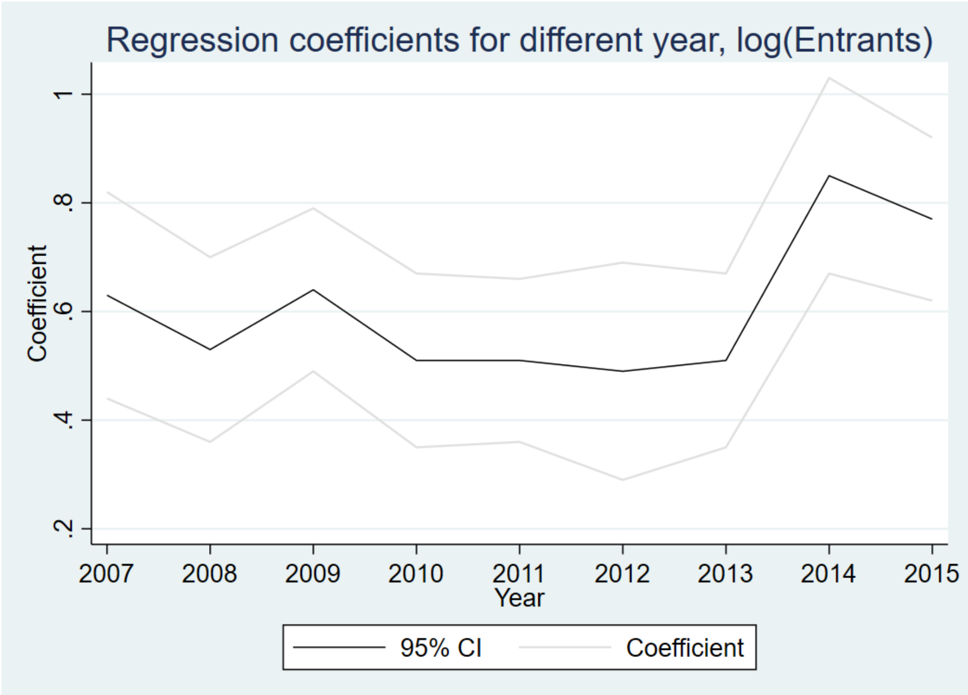
The figure plots the effects of keju on log(Patents) for each year during 2007-2015. The vertical line around each dot represents the 95% confidence interval.

Figure B3: Time varying effects of keju on R&D expenditure



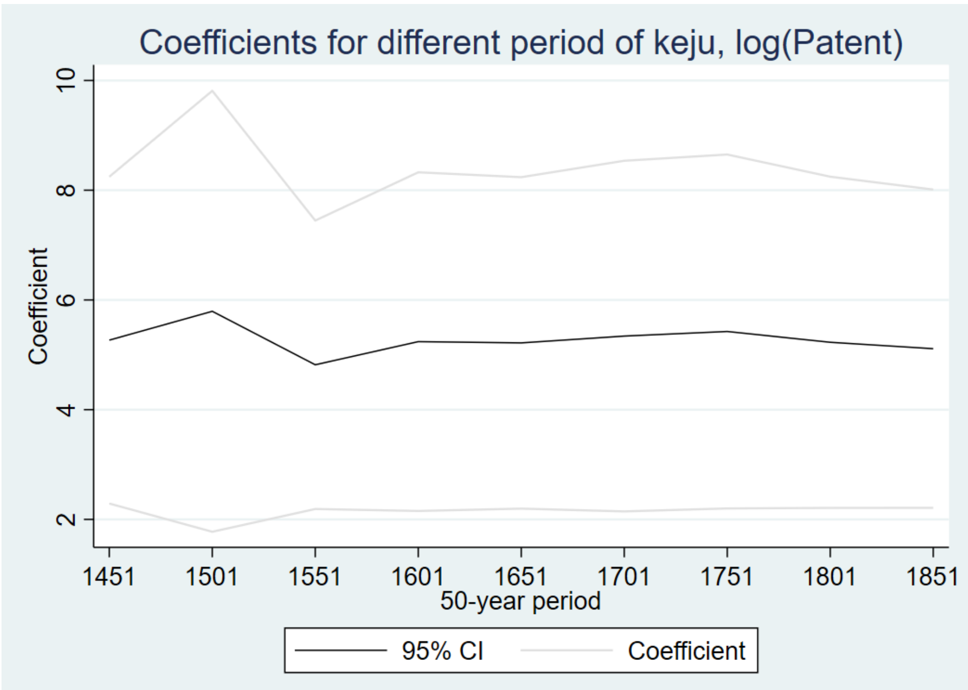
The figure plots the effects of keju on log(R&D) for each year during 2007-2015. The vertical line around each dot represents the 95% confidence interval.

Figure B4: Time varying effects of keju on new entrants



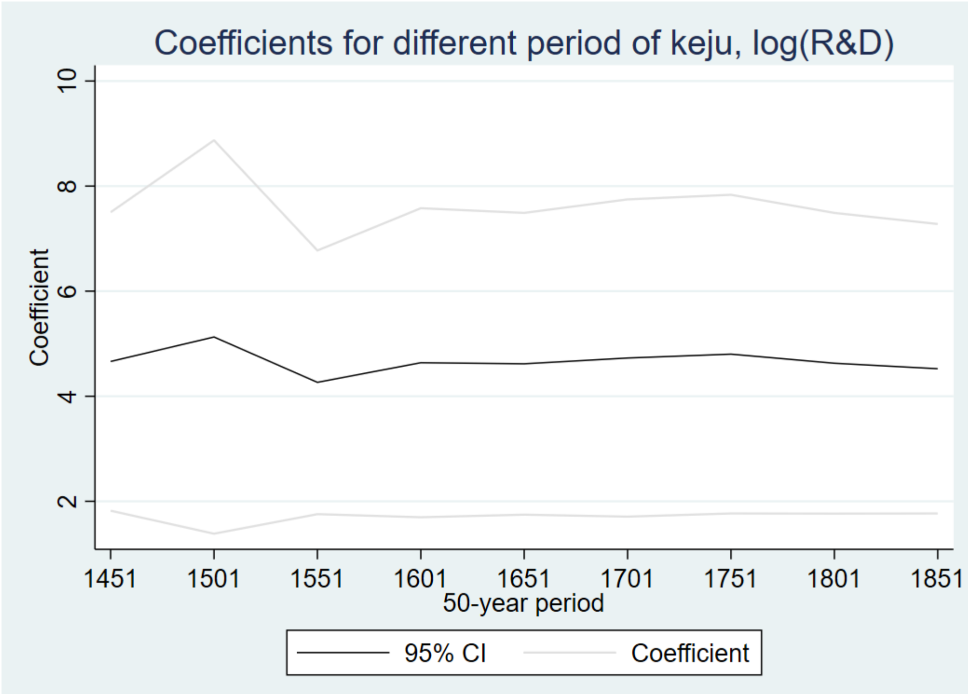
The figure plots the effects of keju on log(Entrants) for each year during 2007-2015. The vertical line around each dot represents the 95% confidence interval.

Figure B5: Time varying effects of keju on patent applications



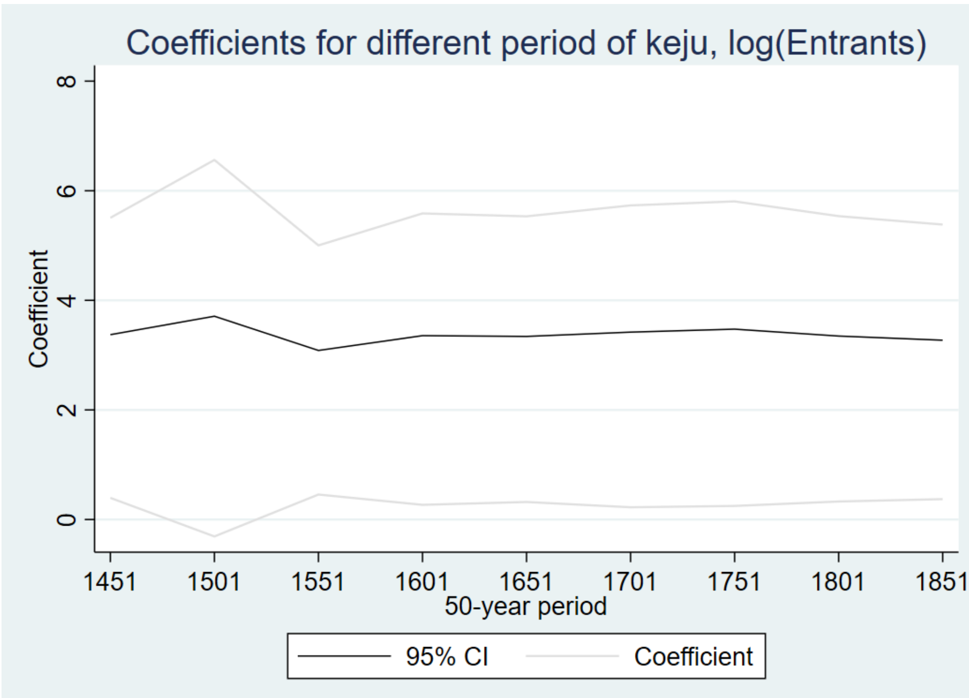
The figure plots the effects of keju on log(Patents) for each different period of keju success. The vertical line around each dot represents the 95% confidence interval.

Figure B6: Time varying effects of keju on R&D expenditure



The figure plots the effects of keju on log(R&D) for each different period of keju success. The vertical line around each dot represents the 95% confidence interval.

Figure B7: Time varying effects of keju on new entrants



The figure plots the effects of keju on log(Entrants) for each different period of keju success. The vertical line around each dot represents the 95% confidence interval.

Table B1: Using Juren density as the main independent variable

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
		IV: Distance to printing materials	
log Juren density	1.088***	0.963***	0.697***
	(0.276)	(0.323)	(0.223)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.667	0.611	0.613

	(4)	(5)	(6)
	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L
		IV: Distance to printing materials	
log Juren density	0.495**	193.3***	3.349**
	(0.249)	(73.86)	(1.630)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.604	0.338	0.773

	(7)	(8)	(9)
	Avg. export/L	log(Patents per firm)	log(R&D per firm)
		IV: Distance to printing materials	
log Juren density	23.36***	0.404***	0.280*
	(8.161)	(0.134)	(0.169)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.559	0.680	0.526

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table B2: Using Shengyuan density as the main independent variable

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
	IV: Distance to printing materials		
log Shengyuan density	18.51	16.39	11.85
	(21.95)	(20.25)	(14.50)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	-16.237	-11.258	-20.698

	(4)	(5)	(6)
	log(Patents)	log(R&D)	log(Entrants, num)
	IV: Distance to printing materials		
log Shengyuan density	8.419	3,290	56.99
	(10.01)	(4,148)	(66.00)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	-4.140	-16.565	-3.133

	(7)	(8)	(9)
	log(Patents)	log(R&D)	log(Entrants, num)
	IV: Distance to printing materials		
log Shengyuan density	397.5	6.883	4.758
	(524.5)	(7.899)	(6.316)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	-11.208	-5.965	-1.943

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table B3: Using data of 1998-2007, ASIF

	(1)	(2)	(3)	(4)	(5)	(6)
	log(Patents)		Avg. revenue/L		Avg. profit/L	
	OLS	IV: Distance to printing materials	OLS	IV: Distance to printing materials	OLS	IV: Distance to printing materials
log jinshi density	0.763**	0.799***	84.54***	69.54***	8.005**	6.614***
	(0.353)	(0.224)	(21.39)	(18.69)	(3.205)	(2.496)
Province FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	272
R-squared	0.652	0.671	0.389	0.415	0.174	0.176

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. "ASIF" stands for Annual Survey of Industrial Firms. * Significant at 10%, ** 5%, *** 1%.

Table B4: Effects on exit

	(1)	(2)	(3)	(4)	(5)	(6)
	log(Exit, num)	log(Exit, cap)	log(Exit, num,SOE)	log(Exit, num, priv)	log(Exit, cap,SOE)	log(Exit, cap, priv)
			IV: Distance to printing materials			
log jinshi density	0.313	0.566**	0.451***	0.381	0.476	0.279
	(0.271)	(0.240)	(0.131)	(0.242)	(0.432)	(0.403)
Province FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	272
R-squared	0.700	0.683	0.742	0.725	0.688	0.681

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table B5: Effects on trademarks

	(1)	(2)	(3)
	log(TM)	log(TM, SOE)	log(TM, private)
	IV: Distance to printing materials		
log jinshi density	0.841***	0.620***	0.842***
	(0.139)	(0.240)	(0.131)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.583	0.586	0.581

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table B6: Talent misallocation and historical development: OLS results

	(1)	(2)	(3)	(4)	(5)	(6)
	log scientist den., Ming	log scientist den., Qing	log pop den. OLS	log school, 1900	Urbanization rate	log Confucian
log non-science jinshi share	-0.00119***	-0.00168***	-0.0102***	0.0429	-0.0288***	-0.161
	(4.63e-05)	(6.71e-05)	(9.83e-05)	(0.0713)	(0.00166)	(0.139)
log jinshi density	1.72e-05	3.52e-05	-0.000738***	0.116	0.00542**	-0.192
	(0.000129)	(0.000194)	(0.000128)	(0.0952)	(0.00224)	(0.284)
Province FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	272	272	272	272	272	272
R-squared	0.826	0.829	1.000	0.866	1.000	0.601

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table B7: Controlling for contemporaneous human capital

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
		OLS	
log jinshi density	0.0624	0.0494	-0.0730
	(0.257)	(0.274)	(0.170)
log years of edu	8.493***	9.039***	5.134***
	(1.163)	(1.666)	(0.683)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.792	0.701	0.740

	(4)	(5)	(6)
	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L
		OLS	
log jinshi density	0.129	29.37	-0.137
	(0.410)	(54.43)	(1.868)
log years of edu	6.289***	1,451***	13.00
	(1.198)	(392.4)	(9.426)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.683	0.448	0.788

	(7)	(8)	(9)
	Avg. export/L	log(Patents per firm)	log(R&D per firm)
		OLS	
log jinshi density	-11.90	0.134	0.121
	(8.072)	(0.142)	(0.167)
log years of edu	144.4**	3.286***	3.831***
	(55.57)	(0.672)	(1.282)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.571	0.751	0.561

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table B8: Creativity and attitudes toward science

	(1)	(2)	(3)	(4)
	Being creative	Pro-science 1	Pro-science 2	Creative task
		Logistic regression		
log jinshi density, provincial average	0.260***	0.323*	0.253	0.272***
	(0.0673)	(0.196)	(0.196)	(0.0677)
Wave FE	Y	Y	Y	Y
Observations	3,820	6,189	6,132	2,861

Notes: The sample is constructed using the World Value Survey. Wave fixed effects are controlled for in each column. "Pro-science1" refers to a dummy variable indicating whether the individual believes that science and technology can make our life easier. "Pro-science2" refers to a dummy indicating whether the individual believes that science and technology can bring more opportunity to our lives. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table B9: Effects on entrepreneurship

	(1)	(2)	(3)	(4)
	log(CEO den.)		log(Legal representative den.)	
	IV: Distance to printing materials			
log jinshi density	1.421***	1.974***	0.764***	0.880***
	(0.432)	(0.417)	(0.128)	(0.119)
Province FE	Y	Y	Y	Y
Controls	Y	N	Y	N
Observations	272	272	272	272
R-squared	0.609	0.538	0.685	0.546

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table B10: Controlling for contemporaneous culture

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
		OLS	
log jinshi density	0.679	0.866*	0.417
	(0.520)	(0.423)	(0.285)
F-test for culture variables	0.000***	0.000***	0.000***
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	103	103	103
R-squared	0.866	0.839	0.854
	(4)	(5)	(6)
	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L
		OLS	
log jinshi density	0.625	257.1	-0.0309
	(0.780)	(174.0)	(2.746)
F-test for culture variables	0.000***	0.000***	0.000***
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	103	103	103
R-squared	0.794	0.746	0.817
	(7)	(8)	(9)
	Avg. export/L	log(Patents per firm)	log(R&D per firm)
		OLS	
log jinshi density	-8.073	0.370	0.557*
	(17.37)	(0.471)	(0.297)
F-test for culture variables	0.000***	0.000***	0.000***
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	103	103	103
R-squared	0.809	0.825	0.768

Notes: The sample covers 103 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table B11: Controlling for contemporaneous institutions

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
		OLS	
log jinshi density	0.0805	0.0187	-0.124
	(0.297)	(0.295)	(0.216)
F-test for institution variables	0.000***	0.000***	0.000***
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.744	0.654	0.692

	(4)	(5)	(6)
	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L
		OLS	
log jinshi density	0.213	-67.92	-2.628
	(0.430)	(71.62)	(1.754)
F-test for institution variables	0.000***	0.000***	0.000***
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.644	0.449	0.798

	(7)	(8)	(9)
	Avg. export/L	log(Patents per firm)	log(R&D per firm)
		OLS	
log jinshi density	-25.58**	0.251	0.190
	(11.53)	(0.158)	(0.204)
F-test for institution variables	0.000***	0.000***	0.000***
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.587	0.728	0.540

Notes: The sample covers 272 prefecture cities in 31 provinces. Controls include log night-light luminosity, log distance to the coast, terrain ruggedness, agricultural suitability, log population density, and Ming-Qing urbanization rates. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Appendix C Data Compilation

C.1 Firm data

The origin data set of the firm registration information consists of records of registration and deregistration of each firm. Each entry includes information on the registry capital, location, identity of the legal representative(s), ownership information, sectoral classification, and the year of exit (if any). Note that if the firm simply stops production or reallocates but does not deregister, then it is not deemed to exit in our data set. However, we also merge the registration data set with the Annual Survey of Industrial Firms data set that has information on production, with a matching rate of 81%. If we take into account the fact that a firm may stop production and count this case as an exit, the new exit should be 2.24% larger, whereas all of the results on exit still hold.

Based on over 40 million registration records of the universe of Chinese firms, we aggregate the granular data into a city-level cross-sectional data set. Specifically, we calculate entry and exit in each city cell. Entry is defined and calculated as the number of firms that have been registered in a specific city during 2007-2015. We discard observations whose registry capital is 0 or belongs to the top 0.1%. Similarly, exit is defined and calculated as the number of firms that have been deregistered in a specific city during 2007-2015. Again, the measure of exit is subject to the issue of measurement error, but we can show that the magnitude of the error is small and does not alter our main results.

We also match the registration data set with the patent application data set, so that we can know which firm applies for which patent. In this way, we calculate the number of patent applications by firms that belong to a certain city cell.

C.2 CFPS data

We construct several dependent variables using the China Family Panel Survey (CFPS) data, including (1) risk attitudes, (2) children's personalities, (3) attitudes and values of education, and (4) reasons for feeling unfairly treated.

As for risk attitudes, the data source is the CFPS data of wave 2014. The questionnaire asks five questions to measure risk attitudes. The questions let the survey respondents choose from an outcome with full certainty—directly gaining 100, 80, 50, 120, and 150 yuan—and an uncertain outcome—gaining 200 yuan with a probability of 0.5. These five questions correspond to 1(Risky 1) to 1(Risky 5) in Table 10.

As for children's personalities, the data source is the CFPS data of wave 2014. The questionnaire asks the parents to evaluate their children's personalities. For example, the questionnaire asks whether the parents think that their children are happy, patient, careful, and so on. The indicators used in the regression analysis, 1(Curious) and so on, are equal to 1 if the parents think that their children are curious about things.

As for interpersonal trust, the data source is the CFPS data of waves 2012, 2014, 2016, and 2018. The questionnaire asks survey respondents to provide a score on their level of trust toward parents, neighbors, Americans, doctors, etc. The higher the score, the higher the level of trust. The trust scores range from 0 to 10. The regressions involving these trust scores as the dependent variable exploit a pooled cross-sectional data set that combines the four waves.

As for the values of education, the data source is the CFPS data of waves 2012, 2014, 2016, and 2018 for educational expenditures, and the data source is 2014 for attitudes toward education. The questionnaire asks the respondents to provide a number of the expenditures on education and textbooks. The questionnaire also asks the respondents to rank the importance of education, The score ranges from 0 to 10, and we construct a dummy variable equal to 1 if the score is weakly greater than 5.

As for reasons for feeling unfair, the data source is the CFPS data of wave 2016. The questionnaire asks survey respondents whether they have been treated unfairly due to gender, income difference, and hukou status, and by the government due to reasons including conflict with the government. We generate a series of dummy variables equal to 1 if the respondents feel that they have been treated unfairly.