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

Xiangyu Shi*

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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. We build and quantify a growth model consistent with such a narrative.

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

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

*Department of Economics, Yale University. Email: xiangyu.shi@yale.edu. For discussion and comments, we thank Ying Bai, Zachery Bleemer, Shuo Chen, Ting Chen, Will Damron, Jose-Antonio Espin-Sanchez, Tianyu Fan, Gerald Jaynes, Naomi Lamoreaux, Marta Prato, Wei Xiang, Taisu Zhang, Xiaobo Zhang, Ben Zou, and participants in various conferences and seminars. We also thank the Center for Enterprise Research (CER) at Peking University for their help with the data.

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 certain historical periods provides a sharp contrast with the growth miracle in the past four decades. 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. Keju was thought to undermine scholars' creative and critical thinking by forcing 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 rigid examination and bureaucratic system (Bai, 2019).[1] However, when keju is no longer in effect to incentivize talents, it leaves modern China with three historical legacies—a higher level of human capital, a more productive and innovative culture, and a market-friendly institution[2] that are all conducive to innovation, entrepreneurship, and, economic growth. These legacies, together with a benevolent government and well-established market-oriented economic policies, led to the growth miracle of modern China.

Using the number of patent applications as a measure for innovation intensity, jinshi (the highest qualification in the imperial exam) density as a measure for the influence of the exam, and the 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 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.[3]

[1]The "eight-legged essay," an important element of the exam, is an example.

[2]The institution and the culture are based on the high level of human capital.

[3]The exclusion restriction holds for exam transportation costs especially when conditioning on key socioeconomic factors such as economic development.

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 and innovative 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 and leading to 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 the accumulation of human capital (Acemoglu et al., 2014), which is arguably the fundamental factor for the Chinese growth miracle.[4] However, since the role of these three legacies goes hand in hand, it is infeasible to quantify their effects using reduced-form regressions. That said, however, we try to separately quantify them using an endogenous growth model in Appendix A.

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. We collected data on whether each jinshi also worked as a scientist or technician or whether his family member did so, and we define such jinshi as a science-related one. Such jinshi are either directly or indirectly related to science and technology, and serve 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 development and with modern-day innovation, business creation, and firm performance. Therefore, keju misallocated talents, resulting in sluggish 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

[4] This argument is also consistent with the quantitative analysis in Appendix A.

[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.

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). The positive effects of jinshi density on various economic outcomes are the most salient after the economic reform and opening up in the PRC era. Thus, keju can explain the rise of modern and contemporary China.[6]

To reconcile the empirical findings, we build and estimate a quantitative endogenous growth model that features innovation and business creation, and conduct a counterfactual experiment based on model estimates.[7] In our model, the imperial examination has three features: it increases human capital and hence raises the supply of skilled labor (human capital channel), increases creativity and thus firms' innovation capacity (culture channel), and lowers entry costs and fosters entrepreneurship (institution channel). These three features can match the empirical findings. Thus, the model can generate predictions that are consistent with the empirical findings. We also estimate the model using a simulated method of moments (SMM). Based on the SMM estimates, we study the productivity and welfare effects of increasing jinshi density by 10%. It lowers the cutoff for entrants and encourages firms to spend more on R&D. As a result, the growth rate of the economy also increases, and welfare is enhanced. Compared to the status quo, increasing jinshi density by 10% enhances the growth rate by 1.7% and welfare by 0.46%. We also separately quantify the importance of these three channels. We find that the first channel, human capital accumulation, is the most quantitatively important.

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

[6]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.

[7]We relegate the analysis in Appendix A.

three historical legacies that can explain the growth miracle of the past four decades.

This paper speaks to four strands of literature. First, it is related to the literature on the determinants of innovation. Cohen (2010) provides a decent summary of the empirical research on innovation. 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. Like this paper, Hsu et al. (2014), Aghion et al. (2016), Akcigit et al. (2016), and Howell (2017) find that institutions also significantly affect innovation. Acemoglu and Cao (2015) and Akcigit and Kerr (2018) both build models about the process of growth and innovation. Kogan et al. (2017) then provide empirical evidence regarding this issue. 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). This paper fills this gap.

Second, this paper contributes to the literature on the persistent impacts of institutions on social value 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 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. Our paper echoes this line of research by documenting that keju, as a persistent institution, nurtures social value that respects education, knowledge, and science.

Third, this paper speaks broadly to the literature on firm dynamics (Melitz, 2003; Atkeson and Burstein, 2010; Acemoglu et al., 2018; Akcigit et al., 2021; Shi et al., 2021; Shi et al., 2022; Shi and Wang, 2022a and Shi and Wang, 2022b). These papers focus on the role of international trade, redistribution policy, environmental factors, and management quality on firm entry, exit, and innovation. However, few papers focus on the role of human capital in shaping firm dynamics, both on the theoretical and empirical side. This paper provides empirical evidence and builds a theoretical model on this related issue of human capital.

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 and a theoretical model whose predictions are all consistent with the empirical results. 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, keju, was originally established in the Song dynasty (c. 960–1276). However, the imperial exam system did not become fully institutionalized until the Ming dynasty (c. 1368–1643). The system lasted till 1905, a few years before 1911, when the last imperial dynasty (the Qing dynasty, c. 1644–1911) was overthrown.

China's imperial exam had three levels. At the entry level was the prefectural exam, the participants who passed were awarded the title of shengyuan. The next level up was the provincial-level exam, which could only be taken by shengyuan. If they passed, they were awarded a juren title. Finally, only those with a juren title could participate in the jinshi exam, which was the final and the highest stage of the imperial exam. Those who passed would be awarded a jinshi title and then were guaranteed a position in the government administration. In the empirical analysis, we use the density of jinshi as the main independent variable, but we also use the density of juren and shengyuan as robustness checks.

China's imperial exam (keju) was regulated by a quota system. The quotas for the jinshi were proportional to the provinces' population and past success in the exam, which also changed little over time. The quotas were also quite stable over most of the Ming-Qing period, and provinces or prefectures rarely lobbied to expand their quotas. Such a mechanism rules out the scenario in which lobbying by each locality endogenously determined the jinshi density.

According to Chen et al. (2020), China's imperial exam had three essential features. The 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 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. 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 below.

3 Conceptual Framework

In this subsection, we describe the role of keju in explaining (1) the growth miracle of modern China in the past four decades; and (2) the sluggish innovation and scientific development in the historical Ming-Qing periods, at the same time. To explain the growth miracle of modern China, we emphasize the effects of keju in contemporaneous human capital accumulation, shaping innovative and productive 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.

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, and yet the accumulation of human capital by keju creates many talents that are innovative and productive and contribute significantly to economic development. Our documentation that human capital leads to innovation and firm creation, is consistent with the literature that currently emerges (Waldinger (2016); Akcigit et al. (2020); Biasi and Ma (2022)).

As Elman (1991) and Chen et al. (2020) argue, keju created a culture that values education and knowledge. In modern 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. Therefore, it is infeasible to separately estimate the contributions of human capital and culture. We will discuss the related empirical evidence in Section 6.

Keju also fosters market-friendly institutions in modern China. As we will document later, cities with a higher level of success in the keju exam have city mayors or city Party Secretaries with higher educational attainment and with a science, engineering, or economics major. These city leaders implement policies that are more market-oriented, fostering a market-friendly institution that helps innovation and business creation. 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.

According to the above analysis, keju can explain the growth miracle in modern China, since it accumulates human capital, shapes innovative and productive cultures, and fosters market-oriented institutions. However, all these mechanisms are only at play when talents are not misallocated. 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, a small proportion of successful exam takers (jinshi) were also a scientist or a technician. However, 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 periods. Therefore, in this paper, we provide a historical narrative that can explain the sluggish development of the Ming-Qing dynasties and modern China's growth miracle, both through the lens of a long-lasting institution, keju.

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.

4.1 Civil Service Examination (Keju) Success 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 of 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 modern 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. We also take a natural log of jinshi density. To deal with observations with value zero, we define keju influence as $\log(1 + jinshi/population)$.[8]

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

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 family member did so, then define such jinshi as a science-related one, and we use this variable as a measure of the inverse of the distortion of talent incentivization. If fewer jinshi in the elite class were devoted to science, the distortion of incentives was stronger and talent misallocation was more salient. 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 classic Western texts into Chinese, including part of Euclid's Elements. To obtain information about each jinshi's career and family background, the data source we exploit is Wikipedia and "A Compilation of Family Biographies of Imperial Examination Figures in the Qing Dynasty." The share of science-related jinshi is 10.36%.

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 B1. 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[9]. 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 B1. We

[9]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).

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 B1.

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 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 modern China and is under the influence of historical keju. The summary statistics can be found in Table B1. 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 B1.

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:[10]

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

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.[11] 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 distance between city i and the nearest place that produces

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

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

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 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.

5.2 Instrumental Variable 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. 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 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.

5.3 Instrumental Variable 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. 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.

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

5.4 OLS Estimation

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

$$y_i = \beta Jinshi_i + X_i\gamma + \lambda_p + u_i, \tag{5}$$

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.[12]

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 B2. 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

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

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 B3, are somewhat smaller than their counterparts in Table B2, 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%.

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 B2 and Table B3. 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 B4 indicate that the instrument relevance condition holds. The first-stage F-statistic is about 10.8, 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 B5, there is no such discernible correlation.

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 C1 and shengyuan in Table C2. In Table C1, 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 too easy, 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. The results are reported in Figures C1,C2, and C3. The plotted coefficients imply that the effects

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: Weather shocks as IV

	(1)	(2)	(3)
	log(Patents)	log(R&D) IV: Weather shocks	log(Entrants, num)
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 IV: weather shocks	Avg. profit/L
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) IV: weather shocks	log(R&D per firm)
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. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

Table 3: Baseline results: Exam transportation costs as IV

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
		IV: 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
		IV: 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)
		IV: 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. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

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 C14. 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 C4, C5, and C6, indicate that the 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 C3. 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 C4 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.

6.2 The Sluggish Development of Ming-Qing Dynasties

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 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. We present the 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. In the longer run, when we evaluate the effects on contemporaneous outcomes, the results are also consistent: the share of non-science-related jinshi is strongly and negatively related to patent applications, R&D intensity, firm entry, and firm performance, according to Table 5. When we control for jinshi density and run an OLS specification, the results (in Tables

C5 and C6) are still robust. Thus, keju may explain the sluggish scientific development in historical periods, and its diversion of human capital also has long-lasting effects.

6.2.1 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 6, 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.

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 7 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.

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 8 reports the results. Jinshi density is relatively weakly associated with the educational attainments of the

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
				IV: Weather shocks			
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: Distance to printing materials			
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%.

Table 5: Effects of human capital diversion by keju

	(1)	(2)	(3)
	log(Patents)	log(R&D)	log(Entrants, num)
		IV: Distance to printing materials	
log non-science jinshi share	-0.819***	-0.725***	-0.525**
	(0.257)	(0.269)	(0.206)
First-stage F statistic		25.835	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.732	0.691	0.633
	(4)	(5)	(6)
	log(Entrants, cap)	Avg. revenue/L	Avg. profit/L
		IV: Distance to printing materials	
log non-science jinshi share	-0.373**	-145.6*	-2.522
	(0.161)	(78.07)	(1.838)
First-stage F statistic		25.835	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.688	0.475	0.775
	(7)	(8)	(9)
	Avg. export/L	log(Patents per firm)	log(R&D per firm)
		IV: Distance to printing materials	
log non-science jinshi share	-17.59**	-0.305***	-0.211*
	(8.612)	(0.109)	(0.123)
First-stage F statistic		25.835	
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.453	0.746	0.579

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 6: 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 7: 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
			IV: 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
			IV: Exam transport 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%.

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 9 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 10 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 B6. 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 B7 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 B8 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.

Table 8: 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 9: Time-varying effects of keju on innovation and business creation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	log(Patent)	log(Firms)	log(Capital)	log(Patent)	log(Firms)	log(Capital)	log(Patent)	log(Firms)	log(Capital)
		2002-2020			1993-2001			1985-1992	
				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)	log(Capital)	log(Firms)	log(Capital)
	1978-1984		1949-1977	
	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 10: 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. Standard errors are clustered at the province level. * Significant at 10%, ** 5%, *** 1%.

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.

6.5.1 The Role of Human Capital

As in Chen et al. (2020), a salient role of keju in shaping modern 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 modern 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 11. 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),[13] we find that contemporaneous human capital also has both statistically and economically significant effects on innovation, business creation, and firm outcomes (Table B9). 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 modern China. However, our analysis indicates that the keju exam is the deeper historical roots of contemporaneous human capital and has persistent effects.

[13]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 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%.

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.[14] 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. 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 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 12. 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 the Appendix. 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 modern 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

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

Table 12: Effects of keju on modern-day culture

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Effects on risk attitude						
	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. 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%.

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 C7, 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.[15] In column (1) of Table C7, 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 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. 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 C8, 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.

Fourth, we examine the impacts of keju on individuals' occupational choices using China Health and Nutrition Survey (CHNS) data. We focus on two outcome variables: whether the respondent is a skilled laborer (a senior professional/technical worker or a skilled worker such as a foreman, group leader, or craftsman), and whether the respondent owns an enterprise. The results reported in Table C9 indicate that in cities more exposed to the impacts of keju, people are more likely to be skilled laborers, which might be conducive to innovation. However, the effects on whether the respondent owns a firm are not statistically significant.

Finally, we test whether cultures may impact innovation and entrepreneurship in modern China. Using the same instrumental variable estimation approach and city-level cross-sectional data,[16] we find that, according to Table B10, the mean level of risk preference, the mean level of

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

[16]Since the distance to the production site of printing materials still provides exogenous variations, this

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 modern China's growth miracle. 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 modern China is that keju facilitates the establishment of a market-oriented institution that is friendly to economic activities including innovation and entrepreneurship. This line of reasoning 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 B11, in which we use the same instrumental variable estimation strategy. A better-educated leader will implement 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.[17] In Table 13, 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

instrumental variable strategy is still valid.

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

construction can be found in the table notes and Appendix D.

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 B12. 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.[18] 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 modern China. 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.

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 14 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, sweat potatoes suitability, and droughts as a measure of environmental conditions. Columns (5) through (8) in Table 14 indicate that these variables are jointly statistically significant. Thus, besides the keju exam, environmental conditions also matter for contemporary economic development.

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

Table 13: 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%.

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 14 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).[19]

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). A quantitative model suggests that keju has significantly positive effects on growth and welfare.

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 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 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.

[19]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 14: 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%.

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Online Appendix

Appendix A Quantitative Model and Analysis

A.1 Model

In this subsection, we lay out an endogenous growth model with firm dynamics. We focus on three channels whereby keju may explain the growth miracle of modern China: increasing human capital, fostering a culture that is beneficial for innovation and entrepreneurship, and establishing market-oriented institutions. The quantitative model is based on the seminal work of Klette and Kortum (2004), and is further adapted from Acemoglu et al. (2018) and Akcigit et al. (2021).[20]

Time is continuous. Representative households have CRRA preference: $U = \int_0^\infty \exp(-\rho t)\frac{C(t)^{1-\gamma}-1}{1-\gamma}dt$. Final goods $C(t) = (\int c_j(t)^{\frac{\epsilon-1}{\epsilon}}dj)^{\frac{\epsilon}{\epsilon-1}}$. Euler equation: $\frac{\dot{C}}{C} = \frac{r-\rho}{\gamma}$. Aggregate output equals aggregate consumption: $Y(t) = C(t)$. Budget constraint of the household: $C(t) + \dot{A}(t) = rA(t) + w_s(t)L_s + w_u(t)$.

There are two types of labor, skilled labor l_s and unskilled labor l_u. Skilled labor is used for innovation and product line maintenance, while unskilled labor is used for production and emission reduction. The supply of skilled and unskilled labor is inelastic. The measure of skilled labor is $L_s\Psi(keju)$, and the measure of unskilled labor is 1. $\Psi(\cdot)$ is a function of keju success, where $\Psi' > 0$.[21] The function $\Psi(\cdot)$ captures the channel of the response of the supply of skilled labor to keju, which is the main idea in Chen et al. (2020).[22] The wage of skilled and unskilled labor is w_s and w_u.

A continuum of intermediate goods is produced with production function: $q_j = z_j l_{uP}$, z_j is the leading-edge productivity draw for j, l_{uP} is the unskilled labor input. Let J be the active product lines where the firm has the leading-edge technology and chooses to produce, and let n be the cardinality of this set. Define $PD = \{z(j_1), ..., z(j_n)\}$ as the set of productivity to produce the related product.

[20] Since we need to generate results regarding firm performance and innovation, we need to embed firm dynamics into traditional endogenous growth models.

[21] To bring the model to the data, we further assume that $\Psi(\cdot)$ takes a log-linear form.

[22] The rise of educational attainments can be understood as an increase in skilled labor supply, according to the effective human capital theory.

Firms differ in terms of their innovative capacities. Upon successful entry, each firm draws its type $\theta \in \{\theta_H, \theta_L\}$, where $Prob(\theta = \theta_H) = \alpha$, $Prob(\theta = \theta_L) = 1 - \alpha$, $\alpha \in (0,1)$, and $\theta_H > \theta_L > 0$. We assume that while low-type is an absorbing state, high-type firms transition to low-type at the exogenous flow rate $\nu > 0$. In addition to the transition from high to low type, each firm is also subject to an exogenous destructive shock at the rate $\phi > 0$. Once a firm is hit by this shock, its value declines to zero and it exits the economy.

Adding one more product (patent) by hiring h skilled workers at the flow rate $X = \tau_1(keju)^\eta \theta^\eta n^\eta h^{1-\eta}$, where $\eta \in (0,1)$ and n is the number of patents the firm already has. Here $\tau_1(keju)$ is an increasing function of keju's success which characterizes the innovation capacity effects of keju.[23] This setting echoes the empirical results that keju fosters a culture that is good for innovation and increases local people's creativity. The cost function of R&D for patent is $C(x, n, \theta) = w_s n x^{\frac{1}{1-\eta}} (\tau_1(keju)\theta)^{-\frac{\eta}{1-\eta}} \equiv w_s n G(x, \theta)$, where $x = X/n$ is the innovation intensity. We assume that the operation of each product requires $\phi > 0$ units of skilled labor.

We assume that research is undirected across all product lines, meaning that firms do not know ex-ante upon which particular product line they will innovate. This implies that their expected return to R&D is the expected value across all product lines. When a firm innovates over a product line j, it increases the productivity of the product line by $\Delta\bar{z}$, where $\bar{z} = \int_0^1 z_j dj$. That is, $z(t+) = z + \Delta\bar{z}$. The firm with the improved technology in product line j takes over this product line, but in principle, the firm that previously had the leading-edge technology might still compete if the current owner tried to set a very high price. Assume that there is a two-stage pricing game between any firm that wishes to supply a product $j \in [0,1]$, whereby each firm first has to enter and pay a small cost $\epsilon > 0$, and then all firms that have entered simultaneously set prices. Since the price setting after entry forces Bertrand competition, the more productive firm will be able to make any sales and profits, and thus only this firm will pay the cost ϵ and enter.

There is a unit measure of potential entrants. Each entrant has access to an R&D technology $G(x^{entry}, \theta_E)$. Thus an entrant wishing to achieve an innovation rate of x^{entry} hires skilled labor of $h^{entry} = \tau_2(keju)G(x^{entry}, \theta_E)$. This specification implies that a potential entrant has access to the same R&D technology that an incumbent with innovative capacity $\theta_E$and a single active product would have had. $\tau_2(keju)$ is a measure of entry cost and is a decreasing function of

[23]To bring the model to the data, we further assume that $\tau_1(\cdot)$ takes a log-linear form.

keju success.[24] It measures the role of keju in establishing a well-functioning market-oriented institution that reduces the burden of firms, especially in the stage of market entry. According to the World Bank Enterprise Survey, inefficient market institutions may lead to reluctance of entry by potential firm owners, and this is a salient issue in developing countries such as China.

Following a successful innovation, the entrant improves the productivity of a randomly chosen product line by $\Delta\bar{z}$, and at this point, the initial type of a firm, $\theta \in \{\theta_H, \theta_L\}$, is also realized. This description implies the following optimization problem for entrants:

$$\max_{x^{entry} \geq 0} \{x^{entry} EV^{entry}(z + \Delta\bar{z}, \theta) - w_s \tau_2(keju) G(x^{entry}, \theta_E)\}. \tag{A1}$$

Exit (of products and firms) has three causes: (1) There is an exogenous destructive shock at the rate $\varphi > 0$, which causes the firm to exit and shut down all its product lines. (2) There will be creative destruction, because of innovation by other firms replacing the leading-edge technology in a particular product line. (3) There will be endogenous obsolescence, meaning that firms will voluntarily shut down some product lines because they are no longer sufficiently profitable relative to the fixed cost of operation.

The inverse demand function is $p_j = C^{\frac{1}{\epsilon}} c_j^{-\frac{1}{\epsilon}}$. The firm with the leading-edge technology can act as a monopolist and thus solves the following maximization problem: $\pi(\hat{z}_j) = \max\{(C^{\frac{1}{\epsilon}} c_j^{-\frac{1}{\epsilon}} - z(keju)^{-1}\hat{z}_j^{-1})c_j\}$. The price p_j satisfies $(\int p_j^{1-\epsilon} dj)^{\frac{1}{1-\epsilon}} = 1$.[25]

Define the relative productivity by $\hat{z} = \frac{z}{w_u}$. Define the aggregate productivity in sector i as $Z_i = [\int z_j^{\epsilon-1} dj]^{\frac{1}{\epsilon-1}}$. Denote the variable X normalized by Z by $\tilde{X}$. Let μ denote the endogenous average creative destruction rate.

[24]To bring the model to the data, we further assume that $\tau_2(\cdot)$ takes a log-linear form.
[25]These formula come from the CES structure of preference.

The stationary value function of low-type firms, V_l, is[26]

$$r\tilde{V}_l(\hat{PD}) = \{\max\{0, \max_{x\geq 0}[\sum_{\hat{z}\in \hat{PD}} [\tilde{\pi}(\hat{z}) - w_s\phi$$
$$+\mu[\tilde{V}_l(\hat{PD} - \hat{z}) - \tilde{V}_l(\hat{PD})] + \frac{\partial \tilde{V}_l(\hat{PD})}{\partial \hat{z}} \frac{\partial \hat{q}}{\partial w_u} \frac{\partial w_u}{\partial t}]]$$
$$- n\tau_1(keju)\tilde{w}_s G(x, \theta_L) + nx[E\tilde{V}_l(\hat{PD} + \{\hat{z} + \Delta\bar{z}\}) - \tilde{V}_l(\hat{PD})] + \varphi(0 - \tilde{V}_l(\hat{PD}))\}\}. \tag{A2}$$

The stationary value function of high-type firms, V_h, is

$$\begin{aligned} r\tilde{V}_h(\hat{PD}) = &\{\max\{0, \max_{x\geq 0}[\sum_{\hat{z}\in \hat{PD}} [\tilde{\pi}(\hat{z}) - w_s\phi \\ &+ \mu[\tilde{V}_h(\hat{PD} - \hat{z}) - \tilde{V}_h(\hat{PD})] + \frac{\partial \tilde{V}_h(\hat{PD})}{\partial \hat{z}} \frac{\partial \hat{q}}{\partial w_u} \frac{\partial w_u}{\partial t}]] \\ &- n\tau_1(keju)\tilde{w}_s G(x, \theta_H) + nx[E\tilde{V}_h(\hat{PD} + \{\hat{z} + \Delta\bar{z}\}) \\ &- \tilde{V}_h(\hat{PD})] + \varphi(0 - \tilde{V}_h(\hat{PD})) + \nu(\tilde{V}_l(\hat{PD}) - \tilde{V}_h(\hat{PD}))\}\}. \end{aligned} \tag{A3}$$

The shares of product lines, of high-type, low-type, and inactive, are Φ^H, Φ^L, and Φ^{NP}, respectively, where $\Phi^H + \Phi^L + \Phi^{NP} = 1$. Unskilled labor market clearing: $\int l_{uP,j}dj + \int l_{uR,j}dj = 1$. Skilled labor market clearing: $G(x_i^{entry}, \theta_E) + \sum_{k\in\{H,L\}} \Phi^k[h_k(w_s) + \phi] = L_s\Psi(keju)$.

Definition A1. *A stationary competitive equilibrium consists of a tuple*

$$\{l_{uP}, \Phi^H, \Phi^L, \Phi^{NP}, x_H, x_L, x^{entry}, h_k(w_s),$$
$$\tilde{V}_h, \tilde{V}_l, \hat{PD}, \{z_j\}, l_{uR}, \mu, w_s, w_u, r\},$$

such that: (1) intermediate goods producers' profit maximization problem is solved; (2) high- and low-type's value function takes the above form; (3) optimal R&D policy is satisfied for high- and low-type firms; (4) optimal entry policy is satisfied; (5) labor market clearing; (6) evolution of productivity follows the above form; (7) the sum of the share of product lines equals 1; (8) Euler equation is satisfied.

[26] The first two lines (inside the summation) include the instantaneous operating profits, minus the fixed costs of operation, plus the change in firm value if any of its products get replaced by another firm through creative destruction at the rate μ, plus the change in firm value due to the increase in the economy-wide wage. This last term accounts for the fact that, as the wage rate increases, the relative productivity of each of the product lines that the firm operates in declines. The third line subtracts the R&D expenditure, expresses the change in firm value when the firm is successful with its R&D investment at the rate x, and shows the change in value when the firm has to exit due to an exogenous destructive shock at the rate φ.

The model can generate the three following predictions.[27]

Prediction A1. *Higher keju success (more jinshi) may make entry and innovation more profitable, due to a higher level of skilled labor supply. This corresponds to the role of keju in raising the level of human capital. Thus the higher the level of keju success, the more entry and innovation there is.*

Prediction A2. *Higher keju success (more jinshi) may make entry and innovation more profitable, due to a higher level of innovation capacity (and, thus, a lower level of innovation cost). This corresponds to the role of keju in fostering a culture that is conducive to innovation and entrepreneurship. Thus the higher the level of keju success, the more entry and innovation there is.*

Prediction A3. *Higher keju success (more jinshi) may make entry and innovation more profitable, due to a lower level of entry cost. This corresponds to the role of keju in establishing market-friendly institutions that relieve the entry burden of new firms. Thus the higher the level of keju success, the more entry and innovation there is.*

These three predictions hold since keju makes entry and innovation more profitable by increasing the supply of skilled labor, and firms' innovation capacity, and by reducing entry costs. These predictions are all consistent with the empirical results.

A.2 Quantitative Exercise

In this section, we first introduce how to calculate the equilibrium defined above, and then discuss how to estimate the model given the calculation outcomes and using the simulated method of moments.

A.2.1 Model Computation

The procedure of computation of the equilibrium follows Acemoglu et al. (2018). The model can be solved computationally as a fixed point of the following vector of six aggregate equilibrium variables

$$\{\tilde{w}^s, \Phi^h, \Phi^l, \bar{\hat{z}}, EY^h(\hat{z} + \Delta\bar{\hat{z}}), EY^l(\hat{z} + \Delta\bar{\hat{z}})\}. \tag{A4}$$

[27]It is infeasible to provide a rigorous mathematical proof of these predictions. However, we can use quantitative results to verify them.

We can solve for the stationary equilibrium by first posing a conjecture for (A4), then solving for the individual innovation decisions, and then verifying the initial conjecture. Specifically, using the guess for these variables:

1. We compute the innovation rates (x^h, x^l, x^{entry}), R&D values (Ω^h, Ω^l), and growth rate g;

2. Using the innovation intensities, we can calculate the stationary equilibrium distribution over active/inactive product lines and over values of $\hat{z}$ by using Lemma 4;

3. We check the labor market-clearing conditions using the innovation intensities and the above distributions and compute the equilibrium wage rates from the market-clearing conditions for skilled and unskilled labor, updating $\tilde{w}^s$;

4. We update the values for $\bar{\hat{z}}$, $E[Y^h(\hat{z}+\Delta\bar{\hat{z}})]$ and $E[Y^l(\hat{z}+\Delta\bar{\hat{z}})]$ by using the productivity distribution and Lemma 3.

This procedure gives us (A4) as a fixed point and also generates the stationary equilibrium distributions of relative productivities. We simulate $2^{128} \times 272$ (2^{128} firms and 272 cities) firms and aggregate entry, exit, and patents (product lines) at the city-year level, and then compute the moments.

A.2.2 Model Estimation

First, we can parameterize the following: (1) $\log(\Psi(keju)) = \Psi_0 + \Psi_1 \log(keju)$ (skilled labor supply as an increasing function of keju success, $\Psi_1 > 0$); (2) $\log(\tau_1(keju)) = a_0 + a_1 \log(keju)$ (innovation capacity as an increasing function of keju success, $a_1 > 0$); and (3) $\log(\tau_2(keju)) = b_0 - b_1 \log(keju)$ (entry cost or entrepreneurship as a decreasing function of keju success, $b_1 > 0$).

The set of calibrated parameters is $\Theta_1 = \{\epsilon, L^S, \eta, \rho\}$. The set of parameters to be externally estimated (by reduced-form regressions) is $\Theta_2 = \{\Psi_1, a_1, b_1\}$. The set of parameters to be internally estimated is: $\Theta_3 = \{\Psi_0, a_0, b_0, \phi, \theta^L, \theta^H, \theta^E, \alpha, \Delta, \nu, \varphi\}$. Θ_3 is estimated using simulated method of moments (SMM)[28].

Following Acemoglu et al. (2018), we set the discount rate equal to $\rho = 2\%$, which corresponds to an annual discount factor 97% (Song et al., 2011). Also, according to the 2005 population census, we set the measure of skilled labor $L^s = 0.118$, which corresponds to the

[28] The statistical properties of SMM are shown in McFadden (1989) and Pakes and Pollard (1989)

share of the population with a college degree. We follow Broda and Weinstein (2006) and set the elasticity of substitution to $\epsilon = 2.9$. Following Blundell et al. (2002) and Hall and Ziedonis (2001) we set the elasticity of innovation with respect to R&D to 0.5.

Θ_2 can be estimated using reduced-form equations. Specifically, Ψ_1 is obtained using population census data and IV regression reported in Table C9. a_1 is estimated using the regression in Table C7. b_1 is estimated using the regression in Table C8. The results of calibration and external estimation are shown in Table C15.

The remaining 11 parameters can be estimated using the simulated method of moments (SMM). We compute the model-implied moments and minimize the gap between the model and the actual data. Specifically, we solve for the following:

$$\min_{\Theta_3} \sum_{i=1}^{18} \frac{|model_i(\Theta_3) - data_i|}{0.5|model_i(\Theta_3)| + 0.5|data_i|}. \tag{A5}$$

We target 18 moments shown in Table C17. We compute the standard errors of the estimates by Bootstrap. The results of the internal estimation are shown in Table C16. We compare the targeted and non-targeted moments between the model and the data in Table C17, and the results show that the model fits the data quite well.

We then conduct a counterfactual experiment based on the model parameters. We examine the welfare effects when increasing the Jinshi density by 10%. The results are shown in Table B13. Increasing Jinshi density raises the productivity of incumbent firms and the supply of skilled labor and, thus, lowers the cutoff for entrants, and encourages firms to spend more on R&D. Thus, compared to the baseline economy, x^{entry}, $q^{h,min}$, and $q^{l,min}$ decrease, and x^h and x^l increase. As a result, the growth rate of the economy also increases, and welfare is enhanced. Compared to the baseline economy, increasing jinshi density by 10% raises the growth rate by 1.7% and welfare by 0.46%.[29] We also separately quantify the effects of three channels: increasing skilled labor supply (human capital channel), increasing innovation capacity (culture channel), and fostering entrepreneurship (institution channel). The first channel is slightly more quantitatively important than the other two, which is also consistent with the empirical findings that increasing the level of human capital is one of the main channels why keju matters for innovation, business creation, and firm performance. In addition, increasing the jinshi level

[29]These quantitative results verify the model predictions in Section 3.2.

by 20% and 50% further reduces entry barriers and raises firms' innovation investments, thus resulting in larger positive growth and welfare effects.

Appendix B Figures and Tables

Table B1: 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 B2: 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 B3: 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 B4: First stage regression

	(1)	(2)
	log jinshi density	
	First stage	
Distance to bamboo and pine	-0.102***	-0.0850***
	(0.0115)	(0.0109)
Province FE	Y	Y
Controls	N	Y
Observations	272	272
R-squared	0.575	0.649

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: 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 B6: 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 B7: 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 B8: 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 B9: 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 B10: 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 B11: 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 B12: 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%.

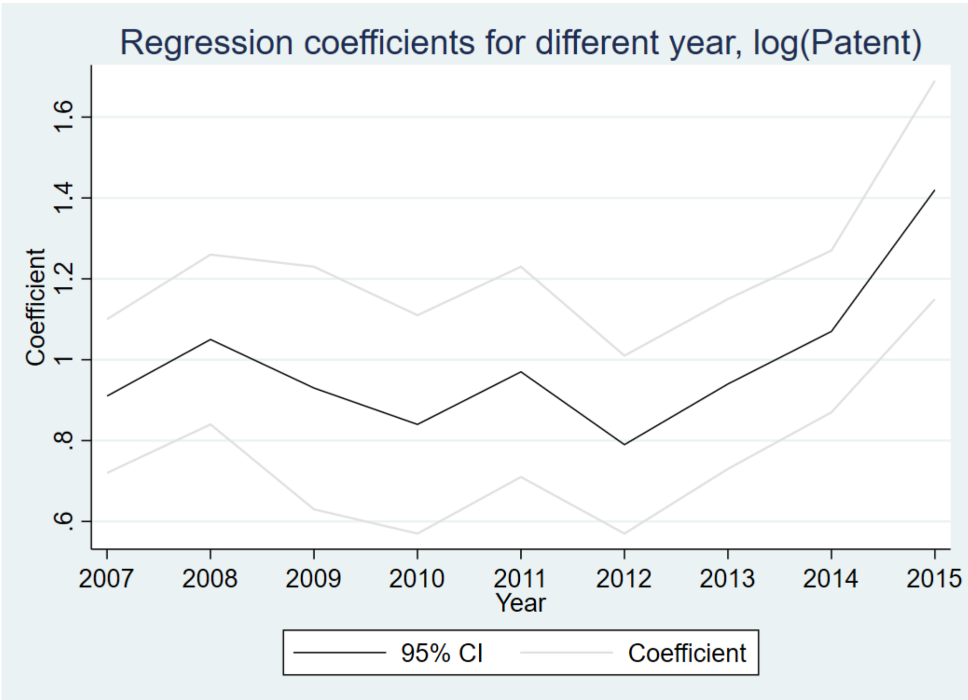
Table B13: Counterfactual experiment

	x^{entry}	x^h	x^l	$q^{h,min}$	$q^{l,min}$	g	$welfare$
Baseline	0.023	0.515	0.284	1.101	1.265	0.047	0.856
Jinshi increase 10%	0.019	0.533	0.292	0.906	1.075	0.048	0.882
Human capital channel	0.020	0.525	0.281	0.940	1.155	0.047	0.834
Culture channel	0.020	0.537	0.306	0.989	1.195	0.045	0.884
Institution channel	0.021	0.537	0.291	0.960	1.122	0.045	0.846
Jinshi increase 20%	0.016	0.542	0.293	0.912	1.062	0.048	0.872
Human capital channel	0.020	0.507	0.288	0.956	1.148	0.047	0.843
Culture channel	0.020	0.534	0.294	0.945	1.163	0.045	0.900
Institution channel	0.020	0.544	0.298	0.957	1.063	0.045	0.870
Jinshi increase 50%	0.015	0.515	0.306	0.926	1.136	0.045	0.917
Human capital channel	0.016	0.530	0.303	0.970	1.089	0.047	0.924
Culture channel	0.017	0.528	0.311	0.923	1.038	0.049	0.932
Institution channel	0.018	0.517	0.312	0.977	1.097	0.045	0.921

Online appendix not for publication, available by request

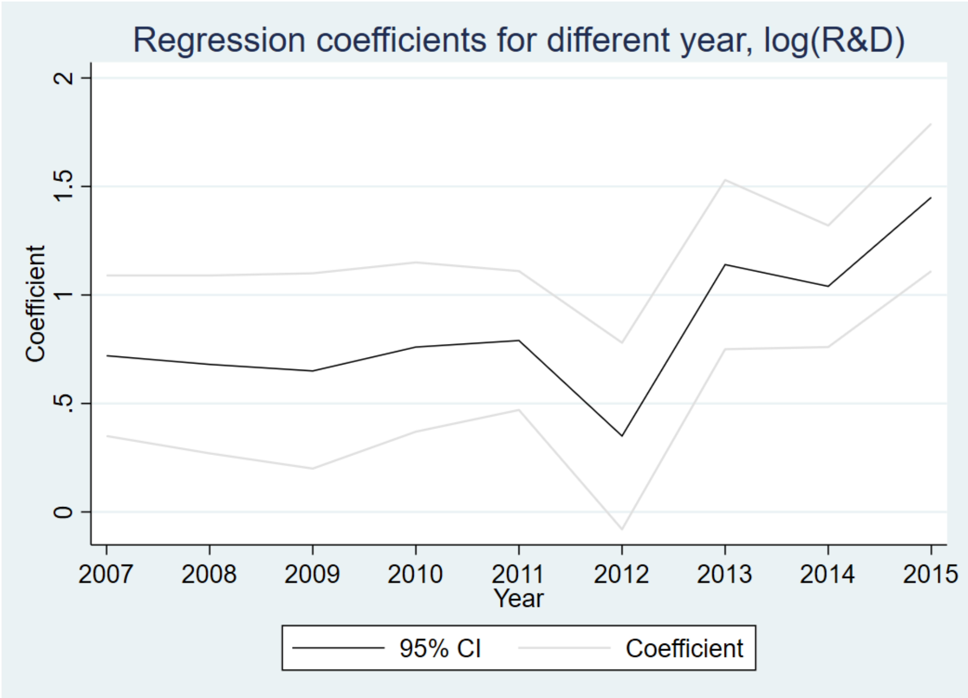
Appendix C Figures and Tables

Figure C1: Time varying effects of keju on patent applications



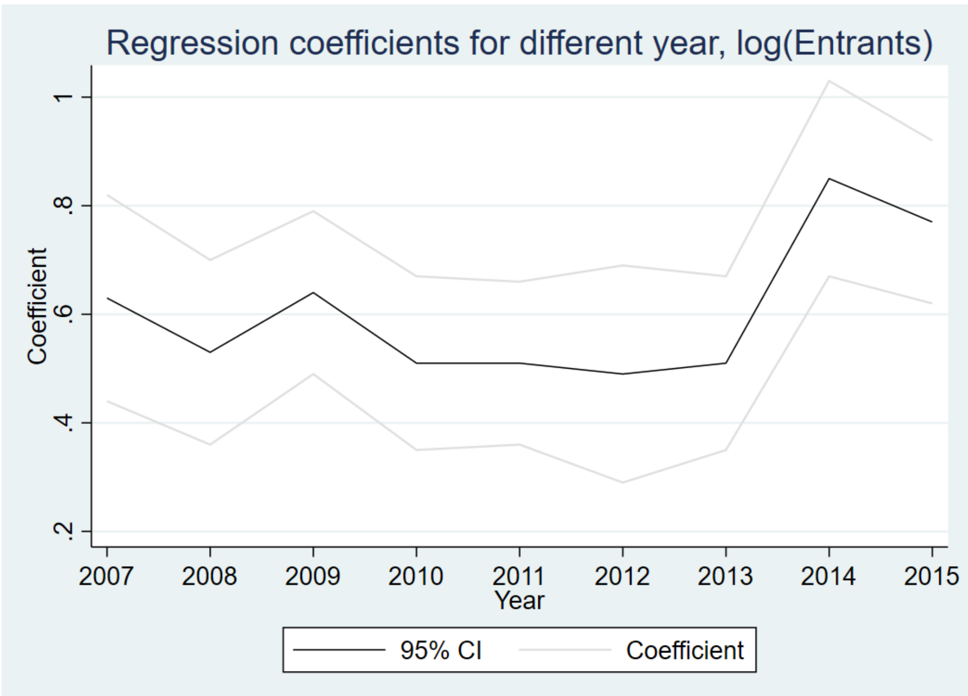
The figure plots the effects of keju on log(Patents) for each year during 2007-2015. The vertical line around each dot represents the 95% confidence interval.

Figure C2: Time varying effects of keju on R&D expenditure



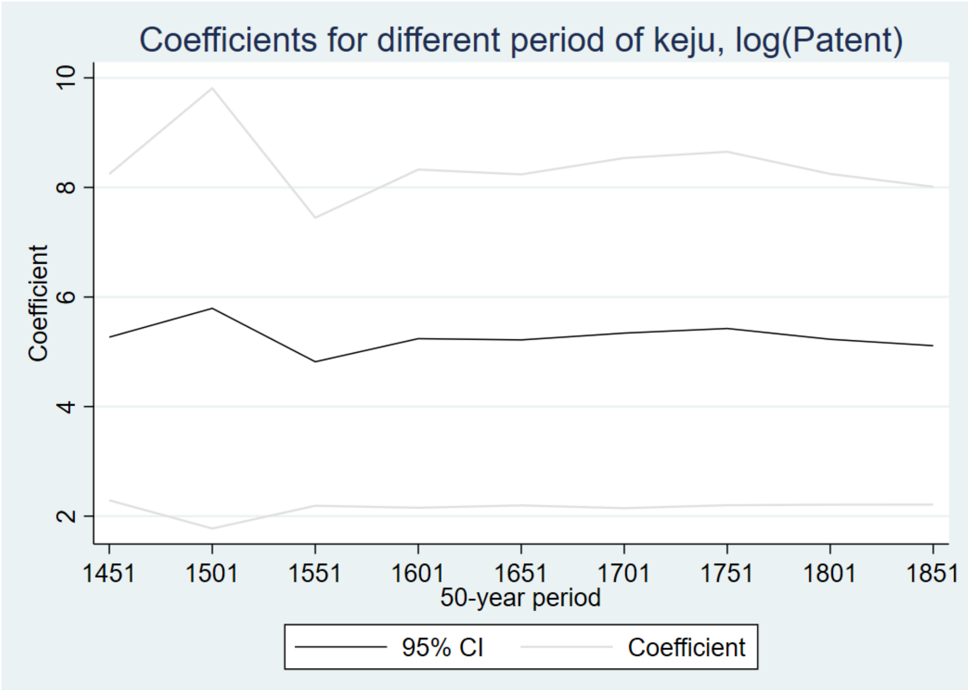
The figure plots the effects of keju on log(R&D) for each year during 2007-2015. The vertical line around each dot represents the 95% confidence interval.

Figure C3: Time varying effects of keju on new entrants



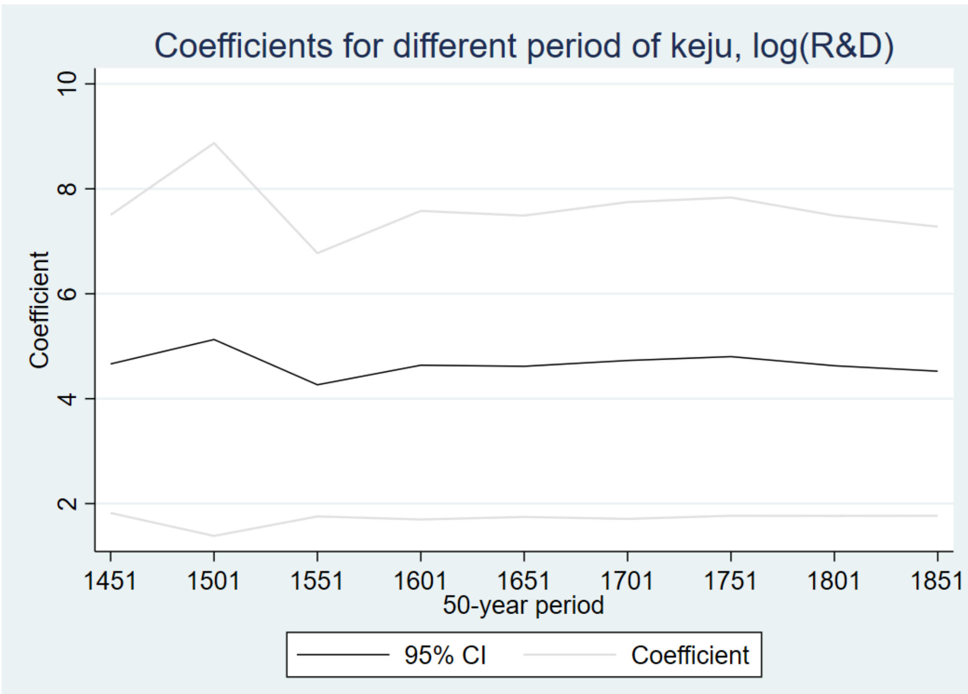
The figure plots the effects of keju on log(Entrants) for each year during 2007-2015. The vertical line around each dot represents the 95% confidence interval.

Figure C4: Time varying effects of keju on patent applications



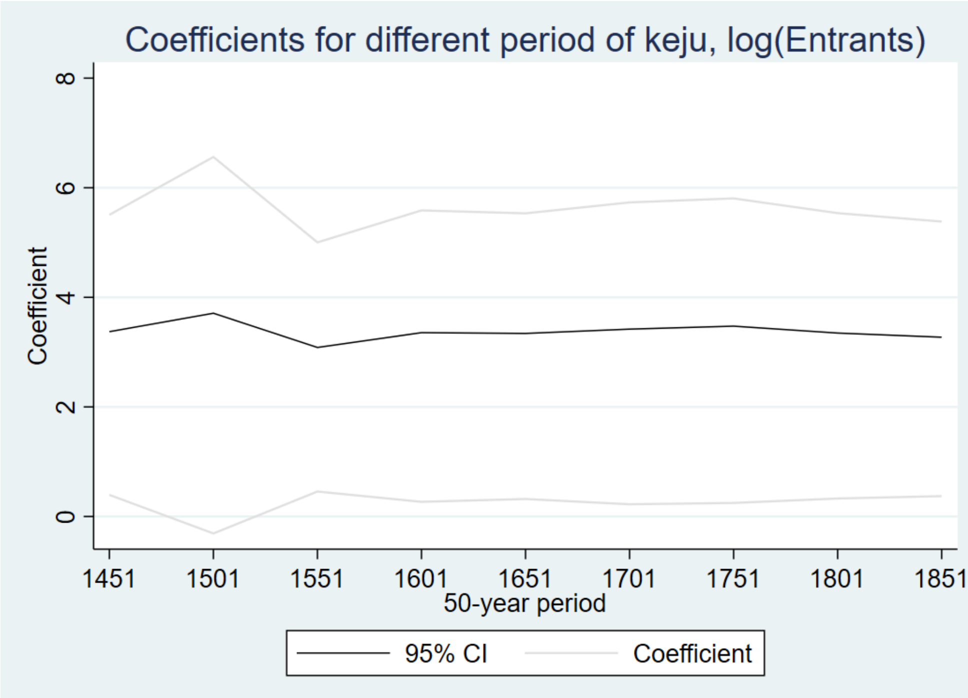
The figure plots the effects of keju on log(Patents) for each different period of keju success. The vertical line around each dot represents the 95% confidence interval.

Figure C5: 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 C6: 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 C1: 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 C2: 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 C3: 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 C4: 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 C5: 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 C6: Talent misallocation and contemporary development: OLS results

	(1)	(2)	(3)
	log(Patents)	log(R&D) OLS	log(Entrants, num)
log non-science jinshi share	-0.679***	-0.809***	-0.358***
	(0.0719)	(0.127)	(0.0390)
log Jinshi density	-0.150	-0.244	-0.0318
	(0.175)	(0.227)	(0.115)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.805	0.733	0.743

	(4)	(5)	(6)
	log(Entrants, cap)	Avg. revenue/L OLS	Avg. profit/L
log non-science jinshi share	-0.617***	-145.2***	-1.176
	(0.0655)	(27.58)	(0.789)
log Jinshi density	-0.279**	12.77	1.156
	(0.111)	(45.91)	(1.179)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.710	0.537	0.800

	(7)	(8)	(9)
	Avg. export/L	log(Patents per firm) OLS	log(R&D per firm)
log non-science jinshi share	-0.292	-0.356***	-0.487***
	(4.164)	(0.0589)	(0.130)
log Jinshi density	15.69*	-0.202*	-0.297
	(8.305)	(0.118)	(0.189)
Province FE	Y	Y	Y
Controls	Y	Y	Y
Observations	272	272	272
R-squared	0.577	0.772	0.605

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 C7: 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 C8: 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 C9: Occupation choice

	(1)	(2)	(3)	(4)
	1(skilled labor)		1(Own a firm)	
	IV: Distance to printing materials			
log jinshi density	0.0501**	0.0629*	0.000857	0.00267
	(0.0233)	(0.0380)	(0.00245)	(0.00409)
Province FE	Y	Y	Y	Y
Controls	N	Y	N	Y
Observations	84,641	84,641	84,641	84,641
R-squared	0.008	0.008	0.001	0.001

Notes: The sample covers 84,641 individuals in 272 prefecture cities and 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 C10: Time-varying effects of talent misallocation on innovation and business creation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	log(Patent)	log(Firms)	log(Capital)	log(Patent)	log(Firms)	log(Capital)	log(Patent)	log(Firms)	log(Capital)
	IV: Distance to printing materials								
	2002-2020			1993-2001			1985-1992		
log non-science Jinshi density	-1.341*	-0.871	-2.164**	-1.127***	-0.221	-0.468	-0.580**	-0.159	-0.156
	(0.687)	(0.529)	(0.993)	(0.353)	(0.283)	(0.523)	(0.225)	(0.122)	(0.312)
First-stage F statistic					25.835				
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	0.101	0.142	0.064	0.068	0.137	0.114	0.073	0.201	0.126

	(10)	(11)	(12)	(13)
	log(Firms)	log(Capital)	log(Firms)	log(Capital)
	IV: Distance to printing materials			
	1978-1984		1949-1977	
log non-science Jinshi density	-0.0388	-0.0322	-0.0266***	-0.0474
	(0.0325)	(0.213)	(0.00722)	(0.129)
First-stage F statistic	25.835			
Province FE	Y	Y	Y	Y
Controls	Y	Y	Y	Y
Observations	272	272	272	272
R-squared	0.233	0.194	0.142	0.085

Notes: The sample covers 84,641 individuals in 272 prefecture cities and 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 C11: 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 C12: 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 C13: 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%.

Table C14: 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 C15: External calibration and estimation

External calibration

Parameter	Value	
ϵ	2.900	
L_s	0.118	
η	0.500	
ρ	0.200	

External Estimation

Parameter	Value	S.E.
Ψ_1	0.226	0.089
a_1	0.357	0.0924
b_1	1.421	0.432

Table C16: SMM estimates

Internal Estimation

Parameter	Value	S.E.
Ψ_0	-0.007	0.001
a_0	0.005	0.0005
b_0	0.008	0.002
ϕ	0.201	0.038
θ_L	1.836	0.023
θ_H	1.444	0.129
θ_E	0.082	0.011
α	0.886	0.174
Δ	0.133	0.022
ν	0.239	0.079
φ	0.056	0.013

Table C17: Model fit

Targeted Moments		
Moments	Data	Model
log(Entry, all)	-1.710	-1.542
log(Entry, large)	-1.326	-1.547
log(Entry, medium)	-1.436	-1.315
log(Entry, small)	-1.481	-1.460
log(Exit, all)	-2.397	-2.150
log(Exit, large)	-1.910	-1.957
log(Exit, medium)	-2.040	-2.212
log(Exit, small)	-1.859	-1.570
log(Patent, all)	-3.140	-3.340
log(Patent, large)	-1.661	-1.920
log(Patent, medium)	-2.508	-2.293
log(Patent, small)	-2.845	-2.909
log(Entry, high keju)	-1.630	-1.619
log(Entry, low keju)	-1.721	-1.701
log(Exit, high keju)	-2.304	-2.288
log(Exit, low keju)	-2.413	-2.421
log(Patent, high keju)	-3.133	-3.098
log(Patent, low keju)	-3.149	-3.155
Non-targeted Moments		
Moments	Data	Model
log(Entry, above median)	-0.897	-0.878
log(Entry, below median)	-0.798	-0.780
log(Exit, above median)	-0.521	-0.550
log(Exit, below median)	-0.479	-0.465

Appendix D Data Compilation

D.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 to 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.

D.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 12.

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.