30TH INTERNATIONAL CONFERENCE OF
AGRICULTURAL ECONOMISTS
JULY 28 – AUGUST 2, 2018 | VANCOUVER

The agricultural root of innovation in China

J. Zhu;

Renmin University of China, School of Agricultural Economics and Rural Development, China

Corresponding author email: zhujiong@ruc.edu.cn

Abstract:

This paper presents evidence in favor of the hypothesis that agricultural legacy matters for shaping the equilibrium level of current innovations. The rice theory (Talhelm et al., 2014) provided a micro foundation for the proposition that people in rice cultivating areas are more inclined toward holistic thinking while wheat cultivating biases one toward analytical thinking. By taking advantages of homogeneity among Han Chinese, this paper proposes and tests the hypothesis that regions that grow rice (the suitability of land for rice production is used as a proxy) tend to inculcate values which promote weak innovations. Using multilevel (province, prefecture, county, and individual level) data within China, the results lend strong support to the proposed idea. Our findings are robust with alternative measures of rice cultivation, with alternative estimation strategies, and with the inclusion of various geographical, socioeconomic, and potentially confounding correlates.

Acknowledgement: The authors thank Tang Zhong, Thomas Talhelm, and Ng Yew-Kwang for helpful discussions and comments, and Liu Meng and Aatishya Mohanty for providing competent research assistance. The usual disclaimers apply.

JEL Codes: B31, Q01

#1387

The agricultural root of innovation in China

Abstract

This paper presents evidence in favor of the hypothesis that agricultural legacy matters for shaping the equilibrium level of current innovations. The rice theory (Talhelm et al., 2014) provided a micro foundation for the proposition that people in rice cultivating areas are more inclined toward holistic thinking while wheat cultivating biases one toward analytical thinking. By taking advantages of homogeneity among Han Chinese, this paper proposes and tests the hypothesis that regions that grow rice (the suitability of land for rice production is used as a proxy) tend to inculcate values which promote weak innovations. Using multilevel (province, prefecture, county, and individual level) data within China, the results lend strong support to the proposed idea. Our findings are robust with alternative measures of rice cultivation, with alternative estimation strategies, and with the inclusion of various geographical, socioeconomic, and potentially confounding correlates.

Keywords: innovations; agriculture; long-run comparative development
JEL classification: Q01; O30; Z10

1 Motivation

The ultimate driver of long-run growth is technical progress and more generally the whole spectrum of innovation from advances in basic science to diffusion of new technologies (Mokyr, 2004; Bénabou, et al., 2013). It therefore seems fairly important to examine which factors may be conducive or detrimental to innovation. In Hicks's pioneering work, he argues that "a change in the relative prices of the factors of production is itself a spur to invention" (Hicks, 1932). Allen (2008) follows this idea and postulates that the relatively high wages is the driving force of three important technologies including spinning jenny, water frame, and carding machine during Industrial Revolution in 18th-century. Acemoglu (2010) then tests the Habakkuk hypothesis (Habakkuk, 1962) that whether scarcity of a factor (and thus high factor prices) leads to technological progress or innovations. He shows that labor scarcity encourages innovations if technology is strongly labor-saving, meaning that innovations encourage the marginal product of labor.

A number of studies have highlighted that a range scope of economic activities are determinants of innovations. Nordhaus (1969) and later studies have emphasized the role of patent laws (e.g. intellectual property rights) in determining the incentives to innovation (see Klemperer, 1990; Gilbert and Shapiro, 1990; Scotchmer, 1991; Sakakibara, 2001; Branstetter, 2001; Lerner, 2002; Cozzi and Galli, 2009; Williams, 2013; Hopenhayn and Squintani; 2015). Porter (1991) claims that tighter environmental regulations will spur innovation. Popp (2002) introduces innovation in climate change models and finds that both energy prices and the quality of existing knowledge have strongly positive effects on innovation. Acemoglu and Linn (2004) investigate the effect of potential market size and pharmaceutical innovation. Using exogenous shocks driven by U. S. demographic trends, they find that increase in the potential market size leads to new products and entities. Hujer and Radic (2005) argue that public policies are crucial to stimulate private innovation when market mechanism is not work. Using the differences between West and East German, they find out that public subsidies have a positive impact on innovations. Pieroni and Pompei (2007) focus on labor market flexibility and propose that higher job turnover has a negative impact on innovations in Northern Italy. Bénabou et al. (2013) uncover a striking negative relationship between religiosity and innovation. Then they relate indicators of individual openness to innovation and show that greater religiosity associated to less innovation (see Bénabou et al., 2015). Cockburn et al. (2017) present that the impact Artificial Intelligence (AI) on innovation. They argue that AI affects the economy by reshaping new method and process of invention.

Innovations are important not only from an economy wide viewpoint but also form an individual firm perspective. Several studies investigate the incentives to innovate at the firm level. In particular, Calabuig and Gonzalez-Maestreb (2002) show that when each firm face its own independent union, its incentive to innovation is higher under decentralized union structures. Aghion et al. (2005) model the relationship between product market competition and innovation. They illustrate an inverted-U relationship between product market competition and innovation (decrease laggard firms but increase neck-and-neck firms). Desmet and Rossi-Hansberg (2011a) demonstrate a mechanism (innovation being localized, land being nonreplicable, and land markets being competitive) that can lead to private innovation by firms in the presence of perfect competition. Guadalupe et al. (2012) use Spanish manufacturing data to analyze the relationship of selection and innovation. They conclude that there are complementarities between innovation activity and the initial characteristics of the acquired firm. Aghion et al. (2013) contrast the "lazy manager" hypothesis and find that institutional ownership boosts innovation.

Recent research favors estimation at a more micro aspect and suggests that household characteristics have strong effect on individual's probability of inventing. Bell et al. (2017) find that parental income, parental occupation and sector of activity, race, gender, and childhood neighborhood are important determinants of the probability of becoming an inventor. Toivanen and Väänänen (2016) look at the effect of education on the probability of becoming an inventor and they find a positive and significant treatment effect. Aghion et al. (2017, forthcoming) postulate individual's IQ has both a direct effect on the probability of inventing as well as an indirect impact through education. Also, income is taken into consideration by Celik (2015) who highlights that Individuals from richer backgrounds are far more likely to become inventors.

This paper is more related to the literatures that test the culture effect on innovations. Mokyr (2002), who postulate that individualistic culture encourages people to act against tradition and conformity and thus, promote innovations. Then Gorodnichenko and Roland (2011a, 2011b, 2012, and 2016) have built an important line of work including both theoretical and empirical evidence focusing on examining whether individualism is the key conduit of innovations. They preform robust empirical studies by using the blood distance between societies as an IV to rule out the reverse causality. Their results support the idea that individualistic countries tend to be more innovative. Moreover, Fogli and Veldkamp (2012) use pathogen prevalence as an IV to achieve the identification as well. Also, it is claimed that some dimensions of culture are related to Industrialization in British (Temin, 1997).

However, despite the important findings of the above studies, the underlying factors that explain innovations have not been thoroughly investigated. In this paper, we seek to explain observed differences in innovation with the help of agricultural legacy. We argue that the agricultural legacy shaped by the environmental suitability of rice farming became a long-run determinant of equilibrium level of innovations. And this effect has persisted long after the majority of the population moved out agricultural sector and ended farming activities.

We measure the innovations by using patents per capita (see Bénabou et al., 2015). Historical agro-ecological information on the proportion of arable land suitable for the cultivation of rice is used as our core variable. To test the main idea of this paper, we perform regression analysis at four different levels: province, prefecture, county, and individual level, respectively. We choose the county as our baseline estimation since China has more than two thousands counties. China is so enormous in size and thus comparisons at the prefecture level or province level would likely conceal high heterogeneity that exists within a province. Our main results consistently provide evidence that the rice suitability is negatively associated with patens per capita. And the relationship between wheat suitability and innovations is positive. Our results hold up to a battery of robustness tests. These include estimations using rice yields as our core variable and controls for agricultural production conditions. The findings remain intact when rice-wheat ratio as the core variable is performed, when different measures of patents per capita are used, and when other crop (maize) is included. Moreover, the coefficients of rice suitability remain robust when we use sub-sample of north and south China, and when we exclude districts and cities, also, when we account several extended controls (GDP per capita, education, aging, migration, agricultural cycle, and religiousness).

This paper proceeds as follows. Section 2 provides a brief review of the related literature. Then the next section provides an account of the relationship between agricultural legacy and innovations. Section 4 describes the estimation strategy, data sources and variable defines. The main results and the robustness checks are presented in Section 5 and Section 6, respectively. Section 7 concludes the paper.

2 Related Literature

In recent years, a number of studies have emerged examining the role of historical events on current economic performance. One of the origins of this literature can be traced to Engerman and Sokoloff (1997) and Sokoloff and Engerman (2000) who postulate that the contemporary income distribution can be explained by the agricultural suitability of wheat to sugarcane. Following their seminal contributions, Nunn and Qian (2011) use the suitability for cultivating potatoes to estimate the impact of the introduction of the potato to Europe, Africa, and Asia. They conclude that the introduction of the potato to the old world from Americas explains an important share of population boost as well as urbanization during the 18th and 19th centuries. Chen and Kung (2012) examine the transfer of maize to China. However, they find that there is no direct evidence to support that maize spurred urbanization rates. Alesina et al. (2013) argue that the location’s suitability for using the plough shaped the cultural norms regarding the role of women.

Jia (2014) examines the diffusion of the drought resistant sweet potato in China and reveal the relation between the occurrence of drought and peasant uprisings. Her study not only highlights that sweet potatoes reduced conflict in China by smoothing consumption during droughts, but also shows how weather shocks differ depending on the historical environment. Bentzen et al. (2013) demonstrates that irrigation is associated with less democracy and more stratified societies. Hansen et al. (2015) test the hypothesis that societies with longer agricultural histories corresponding to higher technological advancement and the transition to cereal agriculture led to division of modern gender roles. Mayshar et al. (2015) propose that the difference between the maximum potential yield for cereals, roots, and tubers can account for the formation of hierarchy and state institutions. Galor and Özaka (2016) provide evidence that the pre-industrial agricultural suitability has persistent effects on the prevalence of long-term orientation in the contemporary age. Iyigun et al. (2017, forthcoming) provide evidence of the long-run effects of a permanent increase in agricultural productivity on conflict.

Talhelm et al. (2014) put forward the rice theory and compare it to the modernization hypothesis and the pathogen prevalence theory to reveal that rice cultivation is one of the determinants of the formation of individualistic norms. The idea that analytic and holistic thinking (individualism and collectivism) has been noted in the cross country literature for a long time (see O’Neill, 1973; Kim, 1994; Triandis, 1995; Vandello and Cohen, 1999) . Their theory is fairly appealing, since it builds the bridge between agriculture practice and culture, psychology, and behaviors. Drawing on their findings, Henrich (2014) propose that wheat farming in Europe may be one of the driving force of industrial revolution. Also, Ang and Fredriksson (2017) show how wheat agriculture affects family ties. They use data from the World Values Survey and the European Values Study and conclude that societies with a legacy in cultivating wheat tend to have weaker family ties. Ang and Gupta (2017) emphasize that higher potential crop yield variability within a country increases the likelihood of intrastate conflict.

3 Agricultural Legacy and Innovations: A Conceptual Link

Our main idea is that agricultural legacy is an important determinant of several key economic outcomes[1]. We argue that agro-ecological differences that determine the feasibility of rice cultivation are important for the change in the equilibrium level of innovation. Rice is the most widely consumed staple food for a large part of the world’s human population, especially in Asia. It is the agricultural commodity with the third-highest worldwide production and provides more than one-fifth of the calories consumed worldwide by humans (Bruce, 1998). Rice is believed to originate from a single 8200 to 13500 years ago in the Pearl River valley region of Ancient China (Molina et al., 2011). Archaeological evidence shows that rice had been domesticated from 10000 to 8000 BC (MacNeish and Libby, 1995).

The idea that rice farming legacy matters innovation differences is straight forward. Areas endowed with environments which are favorable for the cultivation of rice tend to engage more in rice farming. Rice farming requires cooperation and coordination. Rice cultivation fall into groups according to environmental conditions, season of planting, and season of harvest, called ecotypes. Since harvesting rice needs to be done in a short window of time, farmers in rice villages in favor of coordinating their cultivate dates and different families can harvest at different times. This allows them to help in each other’s fields. These labor exchanges commonly occur during harvesting period since urgent labors are needed in a very short time. Also, rice farming requires at least twice working hours as wheat. Single households’ labor forces are unable to farm a large enough plot of rice to support their family (Buck, 1935).

Also, rice requires more water to produce than other grains. It is reported that

---

[1] The contemporary culture in China provides some evidence for the long-run effect of rice farming on current activities. Rice is delicately made into different kinds of foods and Han Chinese only taste these foods in a number of current festivities (Spring Festival, Dragon Boat Festival, and Double-nine Festival). Also, Instead of saying "How are you'", the Chinese use "Have you eaten rice today" as a greeting. Chinese expression says "he/she broke the rice bowl" when someone is fired or rejected for a job.

rice farming uses around one third of earth’s fresh water (see Economists, October 6, 2014). The traditional method for cultivating rice is flooding the fields while, or after, setting the young seedlings. This simple method requires not only ample water, but also servicing of the water damming and channeling. Therefore people build elaborate irrigation systems. Irrigation facilities and networks require people collaborate to build, coordinate water use, and share the cost of construction and maintenance.

Given that the same dynasties have ruled over the rice and wheat areas for most of the past few thousands of years, the ecology patterns have been very different in the two regions (Hoff and Stiglitz, 2016). Rice is labor-intensive and irrigation systems are needed, while wheat, in comparison, is much easier to grow. Wheat is self-fertilized, which means the pollen carried by the stamen of wheat flower impregnates the pistil (stigma and ovary) of the same flower, enabling the variety to breed true. Also, wheat can tolerate severe cold and resume growth with the setting in of warm weather and it depends more on natural rainfall and less on irrigation. Farmers are not even necessary to remain close to the fields during the growing period. Moreover, large labor forces are not required for wheat cultivation. Also, as suggested by Ang and Fredriksson (2017), wheat is mainly cultivated by women, meanwhile adult men and boy focus on securing access to feed and water for the cattle. This gender role encourages trade and then contributes for the formation of specialization which would lower down the potential opportunities to cooperate. In short, all of the above features lead to lower need for inter-dependence, cooperation and coordination in wheat-growing areas.

After thousands of years of farming practice, people living in regions that grow rice develop a deeper root of interdependence and collectivism than those living in wheat areas. Growing up in rice-growing regions biases one toward the use of holistic approaches, whereas growing up in wheat farming environments favors analytical reasoning. “Thinking analytically means breaking things down into their constituent parts and assigning properties to those parts. Similarities are judged according to rule-based categories, and current trends are expected to continue. Holistic thinking, by contrast, focuses on relationships between objects or people anchored in their concrete contexts” (Henrich, 2014). Over time, the higher need for interdependence, cooperation, and coordination and the formation of holistic thinking with a legacy of rice farming led to cultures discourage innovation, novelty, and creativity.

4 Approach and Data

4.1 Regression Model

In order to explore the effect of rice suitability on patents per capita, the following model is estimated via ordinary least squares:

$$PPC_i = \alpha + \beta RS_i + cv\gamma + \varepsilon_i$$

Where *PPC* is patens per capita which is a proxy for innovations, *RS* is the rice suitability value, *cv* is a vector of control variables, and ε is an unobserved error term. It is necessary to control for other effects, since the relationship between rice suitability and patens per capita may be confounded by some omitted influences that not only determine patents per capita but also correlate with the suitability of rice farming.

4.2 Data

This section describes the data used in this paper. It introduced novel global measures of agricultural suitability for rice cultivation as well as wheat that are employed in order to examine their effect on innovation. A detailed list of variables with their definitions and sources are given in the appendix.

A China’s Administrative Boundaries

China’s administrative structure is among the most remarkable of human institutions. Although there have been variations in aggregate boundary of China under different dynasties, the counties, however, have remained as the most stable administrative units (Li et al, 2016). Chinese administrative units at the county level are subdivided into cities (shi), counties (xian), districts (qu), banners (qi), forestry area (linqu), special districts (tequ), and autonomous counties/banners (zizhi xian/qi).

To address the county-level administrative changes from 1999 to 2016, the statistical consistency is ensured by tracking the records documented on the website of the National Bureau of Statistics (NBS)[2]. Counties with name changes and re-designated as districts are regarded as the same county while the combined or dropped counties are not included in the dataset since their boundaries are not remained the same. Note that autonomous counties/banners are excluded since these counties are almost not Han Chinese since homogeneity among the Han population is fairly important in this paper. Four centrally administrated municipalities (Beijing, Tianjin, Shanghai, and Chongqing) are excluded.

Figure 1 and Figure 2 provide the distribution of rice suitability and wheat suitability within China, respectively. Rice suitability extended to areas located in south China while wheat suitable regions almost in north. North and south are divided by the Huai River/Qinling Mountain range.

B Agricultural

We use historical information in the rice agro-ecological suitability as our explanatory variable, defined as the mean of suitability value for rice cultivation in each counties. The data is taken from Global Agro-Ecological Zones (GAEZ), which is jointly developed by International Institute for Applied Systems Analysis (IIASA) and the Food and Agriculture Organization (FAO). The GAEZ database provides crop suitability value for cereal, rice, wheat, maize barley, and sorghum with cells size of 5×5 (i.e., approximately 10km×10km). The GAEZ database uses complex model to capture temperature, humidity, evaporation, soil quality, slope and other agricultural conditions for agricultural production. It is important for our study that the suitability measures we use proxy for historical conditions. Although the data are measured on the baseline period from 1960 to 2000, it is widely accepted that they can be a good

---

[2] http://www.stats.gov.cn/tjsj/tjbz/xzqhdm/index.html

proxies for historical suitability given the fact that agro-ecological conditions change only slowly over time (Nunn and Qian, 2011; Ang and Fredriksson, 2017).

County level geo-referenced crop suitability values in this paper are constructed using ArcGIS software to calculate the mean value for each grid within each county. We use measures capture wetland rice cultivation that occurs under rain-fed conditions with an intermediate level of inputs. These restrictions remove the potential concern by human intervention that resulted in improved irrigation systems and farming technologies that could be correlated with innovations. Hence, our explanatory variable is sufficiently exogenous.

C Innovations

Our dependent variable is the innovation which is measured by patents per capita. The patents are the total number of granted patents for all categories including patents for inventions, industrial designs and utility models. Patent data is obtained from Patent Explorer website. This website supplies archives which contain all patents in China since 1989. Because China's patent right reformed at 2001 and the patent data have been consistently recorded since. Annual data for each county is obtained after 2001. To the best of our knowledge, this is the first paper to use county-level patent data in China. To calculate patents per capita, county-level populations are extracted from China's Sub-counties and Cities Nationwide Demographic Yearbook, supplemented by China Population Census 2010. Patent data in 2016 is excluded since there might have some official delay of patents granted procedure (Ruan et al. 2015).

D Additional controls

Crop suitability is correlated with other geographical characteristics that may have affected the innovation. Hence, we accounts for the potential confounding effects of couples of geographical variables such as distance to coast, elevation, precipitation, temperature, standard deviation of temperature, land cover, as well as latitude. Furthermore, we accounts for socioeconomic controls such as GDP per capita, saving ratio, fiscal gap, agricultural share, provincial capital county, poor county, and food county. County statistical yearbooks published by the National Bureau of Statistics (NBS) are the main data source since such data have been consistently recorded since. Moreover, county-level rice yield data and the agricultural production controls (rice yield, wheat yield, farmland, machine, irrigation, electricity, fertilizer, and pesticide) are taken from prefecture-level Statistical Yearbook in 2002. Only data in 2002 are accessible. Moreover, we controls for the variables that affect innovations. Education, for example, there is no official statistical data for schooling years in each county. We calculate school year data and other data (education, % of pop. older than 65, % of pop. migrate in, agricultural cycle, and religious) from China Census Data in 2000.

5 Main results

5.1 Analysis using county-level data

We first investigate the relationship between rice suitability and patents per capita at county-level. The results are shown in the Table 1. In column (1), the regression shows that higher rice suitability is correlated with lower amounts of patents per capita. It accounts for province dummies and therefore for unobserved time-invariant omitted variables at the province level. The estimated coefficient is negative and statistically significant at the 5% level. The results remain largely intact when north-south dummies are added in column (2). The coefficient remains highly significant at the 1% level when geographical controls (In particular, distance to coast, elevation, precipitation, temperature, std. of temperature, land cover, and latitude) are added in the column (3). Moreover, most geographical characteristics have no significant association with patents per capita.

The next three columns establish the relationship between wheat suitability and patents per capita. The wheat suitability coefficient is significantly positive in column (4) and (5) while it lost significant in the column (6) when geographical controls are included. The last three columns check if the results in column (1) to (3) are sensitive to controlling for the wheat suitability variables. When wheat suitability variables are added to the specification, the results are almost unchanged. In all case, the coefficients of rice suitability are stable and highly significant.

[Table 1]

5.2 Analysis using province-level and prefecture-level data

We also estimate Eq (1) using province-level and prefecture-level data. The results are reported in Table 2 and Table 3. The negative and statistically significant coefficient of rice suitability terms suggests that our main results remain largely intact at province-level and prefecture-level. The baseline controls are excluded in the first three columns. In columns (1) and (4), the univariate regressions show that higher rice suitability is significantly correlated with lower values of patents per capita. In columns (2) and (5), we tend to using wheat suitability as the independent variable, but find that it is not significantly correlated with patents per capita. Column (3) and (6) check if the results in column (1) and (4) are sensitive to controlling for the wheat suitability variables. The results remain intact. From Table 2 and Table 3, we know that our baseline results are highly robust at the province-level and prefecture-level, respectively

[Table 2]

[Table 3]

5.3 Analysis using Rice Yield

It deserved to be highlighted that while the rice suitability is less precise than the actual production data, but one key advantage in that it is exogenous enough, which means ice suitability conditions are orthogonal to human intervention. In particular, the use of suitability data captures the long-run agro-ecological features for rice farming (Nunn and Qian, 2011), hence it is less likely to be affect by technological advancements. Also, as suggested by Ang (2015 forthcoming), the cross country evidence shows that the correlation coefficient of rice suitability and actual rice production reaches 0.95. At the county-level data in China, the correlation coefficient of rice suitability and actual rice yield in 2002 is 0.52.

In this part, the actual rice yield data is used as the robustness check for our baseline regression. Aside from former controls, the variables (farmland, machine, irrigation, electricity, fertilizer, and pesticide) that account for agricultural productivity are also included.

The results reported in Table 4 indicate that the substitute using rice yield and the inclusion of these productivity indicators does not alter the main findings. The effects of some productivity variables (namely, Farmland and Fertilizer) are found to be statistically significant at 1% the level. In all case, the coefficients of rice yield remain negative and highly significant at the 1% level. The coefficient of wheat yield is positive and nonsignificant. Although using actual yield data may suffer from endogenous, the results confirm that the effect of rice cultivation on innovations.

[Table 4]

5.4 Analysis using Chinese General Social Survey (CGSS) Individual- Level Data

Next, we tend to investigate the relationship between rice suitability and innovation using individual-level data from Chinese General Social Survey (CGSS). Accordingly, in Table 5 we regress individual responses that capture the attitudes towards science and technology on the degree of rice suitability. We use the information for rice suitability at the county level. Results in column (1) show the ordinary least squares estimate for the effect of rice suitability on belief in science and technology. There is a negative and statistically significant relationship when no control variables are considered. The magnitude of the coefficients of rice suitability varies slightly and the R-squared value increase marginally when standard individual characteristics are considered in column (2). The regression controls for age, age squared, gender, marital status, education, income, and house size. Column (3) and (4) present the results by using wheat suitability. The next two columns check if the coefficients of rice suitability are stable when wheat suitability is considered. In all case, the coefficients on rice suitability remain highly statistically significant. This estimation again gives consist evidence.

[Table 5]

6 Robustness of Estimates

6.1Analysis using Alternative Measure by Rice-wheat Ratio

Our research proposes that after thousands of years of rice farming practice, people living in rice-growing regions develop holistic thinking and a higher degree of interdependence. We then focus on rice suitability as the key condition that explains the equilibrium level of current innovations. This is meant to say that its counterpart, wheat farming, can also affect innovations since wheat cultivation is important for the formation of analytical thinking. Following Easterly (2007), we use a unified variable Rice-wheat Ratio defined as the log of the share of rice suitability on wheat suitability, namely, Log[(1+rice suitability)/(1+wheat suitability)] to reveal our main idea.

Table 6 reports the results, column (1) to (4) include different set of controls. The coefficient of rice-wheat ratio is negative and statistically significant. Overall, the results provide considerable support for our hypothesis.

[Table 6]

6.2 Controlling for the Effect of GDP per capita, Education, Aging, Migration, Agricultural Cycle, and Religiousness

The effect of rice suitability on patents per capita might confounded by the plausible influences of several variables. Our main results might be biased due to failure to account for these variables. Hence we control for GDP per capita, education, aging, migration, agricultural cycle, and religiousness. Given that many of these additional controls represent the contemporary economic conditions, we did not include then in the baseline estimations.

In principle, the negative association between rice suitability and innovations uncovered so far might subject to the problem of omitted factors even when geographical and socioeconomic controls are included. In Table 7, first, we account for GDP per capita. It is the most important factor and as expected, the coefficient is positive and highly significant at 1% level. Second, we control for education level (average school years of whole population). As expected, the coefficient of education is positive and statistically significant at 1% level. Third, it is widely perceived that individuals are more productive and innovated at a younger age (Haltiwanger et al., 1999). Hence, share of population older than 65 as well as share of population younger than 15 are taken into consideration in column (3) and (4). Fourth, as suggested by Ruan et al. (2015), applicants for patents may not come from the counties where the patents are filed. To mitigate this concern, we account for the share of population migrate in from outside. In column (5), higher share of population moved in corresponding with higher patents per capita. The coefficient of rice suitability remains intact. Fifth, in a related study, Bénabou et al. (2013, 2015) uncover a negative relationship between religiosity and innovation. A highly significantly reverse relationship between religiosity and innovations is shown in column (6) and the coefficient of rice suitability is also rather consistent when religiousness variable (number of Buddhist temples) are added in the regression. Overall, the above results suggest that rice suitability has a stronger power in explaining the shaping of innovations, providing considerable support for our main idea.

[Table 7]

6.3 Analysis using alternative mean of patents per capita

No patent data before 2000 is analyzed because China’s patent law was reformed in 2001, and the granted patent data have been consistently recorded since. It should be highlight that the patent data in 2001 to 2005 is relatively small and some data is also not recorded for several reasons. Patent data in 2001 to 2005 is excluded in our baseline estimation. It also should be highlight that patent data in 2016 is not included since there may be an official time lag from submitting a patent and for receiving an approval (Ruan et al., 2015). Hence, our baseline regression covers the period from 2006 to 2015 and we use different mean of patents per capita as robustness check in this section.

Table 8 reports the findings using different mean of patents per capita as the dependent variable. The results are largely unchanged when patents per capita are using mean of 2006 to 2010, 2011-2015, and 2001 to 2015. The coefficient of rice suitability is negative and statistically significant at 1% level. The results provide considerable support for the baseline estimation.

[Table 8]

6.4 Analysis using Alternative Cereal Crops: Maize

Hu and Yuan (2015) argue that there would be an equal chance for maize (corn) cultivation to affect people in wheat-growing north. Three most widely planted crops in China are rice, wheat, and maize. Also, the crops that provide the highest levels of energy are rice (787), maize (748), and wheat (727), where numbers of energy produced in 10^{18} kilogram calories are showed in parenthesis (Mayshar et al., 2015). Accordingly, in this robustness exercise, we tend to exam our main findings against the use of maize cultivation.

In Table 9, we report the regression results using variable maize suitability and maize yield. Columns (1), (2) and (3) regress patents per capita on maize cultivation. North-south dummies and baseline controls are excluded in column (1) and baseline controls are excluded in column (2). In general, the coefficients of maize are negative and statistically significant. In column (4) to (6), we test our main idea and maize suitability is included. The coefficients of rice remain negative and highly statistical significant at 1 % level. Moreover, it remains consistent when wheat suitability is included.

Given that maize was present on in America before 1500 AD and was introduced to the Old World during the Columbian Exchange. Perhaps our robustness check results suggest that only crops that had been domesticated early than 1500 AD, namely rice and wheat, matter for contemporary economic activities.

[Table 9]

6.5 Analysis using Sub-Sample of North & South China

Follow Chen et al. (2013) and Ebenstein (2017), we use the Huai River/Qinling Mountain to divide southern areas that have traditionally farmed mostly rice from northern areas that have farmed mostly wheat. It should be highlight that Yangtze Rice is less precise than Huai River/Qinling Mountain. In particular, Huai River/Qinling Mountain covers 62 counties (Aba, Bagongshan, Batang, Baiyu, Bangshan, Binhai, Chenggu, Datong, Dege, Derong, Dengzhou, Fengtai, Foping, Funing Ganzi, Hongze , Huaiyuan, Huaishang, Huaiyin, Jiuzhaigou, Lixin, Lianshui, Linquan, Liuba, Longzihu, Lueyang, Mian, Neixia, Ningshan, Panji, Pingwu, Pingyu, Qingchuan, Queshan, Rangtang, Runan, Ruyang, Ruoergai, Seda, Shangnan, Sheyang, Shiqu, Tanghe, Tianjiaan, Wuhe, Xixia, Xianggelila, Xiejiaji, Xincai, Xinye, Xunyang, Yang, Yuhui, Yunxi, Zhenan, Lushui, Sihong, Yicheng, Yingdong, Yingquan, Yingzhou).

It is appropriate to test our hypothesis within China by taking advantages of homogeneity among Chinese. China is over 90% Han Chinese (117 autonomous counties/banners are excluded in this paper) and they share the same language, politics, climate, to name a few. As is shown in Figure 1 and Figure 2, rice suitability regions are almost located in southern China while wheat suitability areas are located in north. We run the regression for each sub-sample (north and south). In Table 10, column (1), (2) and (3) report the southern China sample. The coefficient of rice suitability is negative and statistically significant at 1% level while coefficient of wheat suitability is positive and insignificant. Column (4), (5) and (6) show the north sample. Although the rice suitable lands in north are relatively small, the coefficient of rice suitability remains negative and significant. The coefficient of wheat suitability is positive and strong significant. The sub-sample evidence again supports our hypothesis that higher rice suitability predicts weaker patents per capita.

[Table 10]

6.6 Exclusion of Districts, Cities, and Banners

As one may argue that the administrative systems at the county level are different (e.g. the fiscal systems of districts are not as same as the other type of counties). To mitigate this concern, we regress patents per capita on rice suitability by excluding district, cities, respectively. In Table 11, column (1), (2) and (3) report the results without district sample, which show the negative and statistically significant coefficient of rice suitability as well as positive and statistically significant coefficient of wheat suitability. The next three columns show the results exclude cities and the coefficients of rice are negative and statistically significant. In all case, the results remain stable to our baseline estimations.

[Table 11]

7 Concluding Remarks

Innovation is the main engine of growth and it is fairly important to understand what determinants may be conducive to innovation. Although a large body of literature provides important evidence that several factors can affect innovation. However, the driving forces of innovation still remain largely unexplored. To address this pattern, we propose and test the hypothesis that innovation is linked to the specific conditions of agricultural legacy.

Using data at the province, prefecture, county, and individual level, this study consistently demonstrates that innovations are associated with agricultural legacy. We find strong robust results that rice suitability have a strong negative effect on patents per capita. Our findings indicate that after thousands of years of rice farming practice, the agricultural legacy has yield a lower equilibrium level of innovations. This is because people living in rice-growing areas are more inclined toward holistic thinking and develop a higher degree of inter-dependence, cooperation, and coordination. Hence lower down the ability of innovation, novelty, and creativity.

Reference

Acemoglu D, Linn J. Market size in innovation: theory and evidence from the pharmaceutical industry[J]. The Quarterly Journal of Economics, 2004, 119(3): 1049-1090.

Acemoglu D. When does labor scarcity encourage innovation?[J]. Journal of Political Economy, 2010, 118(6): 1037-1078.

Aghion P, Akcigit U, Hyytinen A, et al. The Social Origins of Inventors[R]. National Bureau of Economic Research, 2017.

Aghion P, Bloom N, Blundell R, et al. Competition and innovation: An inverted-U relationship[J]. The Quarterly Journal of Economics, 2005, 120(2): 701-728.

Aghion P, Van Reenen J, Zingales L. Innovation and institutional ownership[J]. The American Economic Review, 2013, 103(1): 277-304.

Alesina A, Giuliano P, Nunn N. On the origins of gender roles: Women and the plough[J]. The Quarterly Journal of Economics, 2013, 128(2): 469-530.

Allen R C. Why the industrial revolution was British: commerce, induced invention, and the scientific revolution[J]. The Economic History Review, 2011, 64(2): 357-384.

Ang J B, Fredriksson P G. Wheat agriculture and family ties[J]. European Economic Review, 2017, 100: 236-256.

Ang J B, Gupta S K. Uncovering The Deep Roots of Conflict[R]. Nanyang Technological University, School of Humanities and Social Sciences, Economic Growth Centre, 2017.

Ang J B. Agricultural Legacy, Individualistic Culture, and Techology Adoption[R]. Nanyang Technological University, School of Humanities and Social Sciences, Economic Growth Centre, 2015.

Bell A M, Chetty R, Jaravel X, et al. Who Becomes an Inventor in America? The Importance of Exposure to Innovation[R]. National Bureau of Economic Research, 2017.

Bénabou R, Ticchi D, Vindigni A. Forbidden fruits: the political economy of science, religion, and growth[J]. 2013.

Bénabou R, Ticchi D, Vindigni A. Religion and innovation[J]. The American Economic Review, 2015, 105(5): 346-351.

Bentzen J S, Kaarsen N, Wingender A M. Irrigation and autocracy[J]. Journal of the European Economic Association, 2017, 15(1): 1-53.

Branstetter L G. Are knowledge spillovers international or intranational in scope?: Microeconometric evidence from the US and Japan[J]. Journal of International Economics, 2001, 53(1): 53-79.

Buck J L. Land Utilization in China: A Study of 16,786 Farms in 168 Localities, and 38,256 Farm Familites in Twenty-two Provinces in China, 1929-1933--Statistics[M]. Commercial Press, Limited, Agents in the United States, The University of Chicago Press, 1937.

Calabuig V, Gonzalez-Maestre M. Union structure and incentives for innovation[J]. European Journal of Political Economy, 2002, 18(1): 177-192.

Celik M A. Does the Cream Always Rise to the Top? The Misallocation of Talent and Innovation[J]. Unpublished, University of Pennsylvania, 2015.

Chen S, Kung J K. Of maize and men: the effect of a New World crop on population and economic growth in China[J]. Journal of Economic Growth, 2016, 21(1): 71-99.

Chen Y, Ebenstein A, Greenstone M, et al. Evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River policy[J]. Proceedings of the National Academy of Sciences, 2013, 110(32): 12936-12941.

Cockburn I M, Henderson R, Stern S. The Impact of Artificial Intelligence on Innovation[M]//Economics of Artificial Intelligence. University of Chicago Press, 2017.

Cozzi G, Galli S. SCIENCE‐BASED R&D IN SCHUMPETERIAN GROWTH[J]. Scottish Journal of Political Economy, 2009, 56(4): 474-491.

Desmet K, Rossi‐Hansberg E. On spatial dynamics[J]. Journal of Regional Science, 2010, 50(1): 43-63.

Easterly W. Inequality does cause underdevelopment: Insights from a new instrument[J]. Journal of Development Economics, 2007, 84(2): 755-776.

Ebenstein A, Fan M, Greenstone M, et al. New evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River Policy[J]. Proceedings of the National Academy of Sciences, 2017, 114(39): 10384-10389.

Engerman S L, Sokoloff K L. Factor endowments, institutions, and differential paths of growth among new world economies[J]. How Latin America Fell Behind, 1997: 260-304.

Fogli A, Veldkamp L. Germs, social networks and growth[R]. National Bureau of Economic Research, 2012.

Galor O, Özaka Ö. The agricultural origins of time preference[J]. The American Economic Review, 2016, 106(10): 3064-3103.

Gilbert R, Shapiro C. Optimal patent length and breadth[J]. The RAND Journal of Economics, 1990: 106-112.

Gorodnichenko Y, Roland G. Culture, institutions and the wealth of nations[J]. Review of Economics and Statistics, 2016 (0).

Gorodnichenko Y, Roland G. Individualism, innovation, and long-run growth[J]. Proceedings of the National Academy of Sciences, 2011, 108(Supplement 4): 21316-21319.

Gorodnichenko Y, Roland G. Understanding the individualism-collectivism cleavage and its effects: Lessons from cultural psychology[M]//Institutions and comparative economic development. Palgrave Macmillan UK, 2012: 213-236.

Gorodnichenko Y, Roland G. Which dimensions of culture matter for long-run growth?[J]. The American Economic Review, 2011, 101(3): 492-498.

Guadalupe M, Kuzmina O, Thomas C. Innovation and foreign ownership[J]. The American Economic Review, 2012, 102(7): 3594-3627.

Habakkuk H J. American and British Technology in the Nineteenth Century: The search for labour saving inventions[M]. Cambridge University Press, 1962.

Haltiwanger J C, Lane J I, Spletzer J R. Productivity differences across employers: The roles of employer size, age, and human capital[J]. The American Economic Review, 1999, 89(2): 94-98.

Hansen C W, Jensen P S, Skovsgaard C V. Modern gender roles and agricultural history: the Neolithic inheritance[J]. Journal of Economic Growth, 2015, 20(4): 365-404.

Henrich J. Rice, psychology, and innovation[J]. Science, 2014, 344(6184): 593-594.

Hicks J R. Marginal productivity and the principle of variation[J]. Economica, 1932 (35): 79-88.

Hoff K, Stiglitz J E. Striving for balance in economics: Towards a theory of the social determination of behavior[J]. Journal of Economic Behavior & Organization, 2016, 126: 25-57.

Hopenhayn H A, Squintani F. Patent rights and innovation disclosure[J]. The Review of Economic Studies, 2015, 83(1): 199-230.

Hu, Shihu, and Zhiguo Yuan. 2015. “Commentary on 'Large-Scale Psychological Differences within China Explained by Rice versus Wheat Agriculture.'” Frontiers in Psychology 6:489–90.

Hujer R, Radić D. Evaluating the impacts of subsidies on innovation activities in Germany[J]. Scottish Journal of Political Economy, 2005, 52(4): 565-586.

Iyigun M, Nunn N, Qian N. Winter is coming: The long-run effects of climate change on conflict, 1400-1900[R]. National Bureau of Economic Research, 2017.

Jia R. Weather shocks, sweet potatoes and peasant revolts in historical China[J]. The Economic Journal, 2014, 124(575): 92-118.

Kim U E, Triandis H C, Kâğitçibaşi Ç E, et al. Individualism and collectivism: Theory, method, and applications[M]. Sage Publications, Inc, 1994.

Klemperer P. How broad should the scope of patent protection be?[J]. The RAND Journal of Economics, 1990: 113-130.

Lerner J. 150 years of patent protection[J]. American Economic Review, 2002, 92(2): 221-225.

Li P, Lu Y, Wang J. Does flattening government improve economic performance? Evidence from China[J]. Journal of Development Economics, 2016, 123: 18-37.

MacNeish R. S. and Libby J. eds. (1995) Origins of Rice Agriculture. Publications in Anthropology No. 13

Mayshar J, Moav O, Neeman Z, et al. Cereals, appropriability and hierarchy[J]. 2016.

Mokyr J. Accounting for the industrial revolution[J]. The Cambridge economic history of modern Britain, 2004, 1: 1-27.

Mokyr J. Innovation in an historical perspective: Tales of technology and evolution[M]//Technological innovation and economic performance. Princeton University Press, 2002.

Molina, J.; Sikora, M.; Garud, N.; Flowers, J. M.; Rubinstein, S.; Reynolds, A.; Huang, P.; Jackson, S.; Schaal, B. A.; Bustamante, C. D.; Boyko, A. R.; Purugganan, M. D. (2011). "Molecular evidence for a single evolutionary origin of domesticated rice". Proceedings of the National Academy of Sciences. 108 (20): 8351.

Nordhaus W D. An economic theory of technological change[J]. The American Economic Review, 1969: 18-28.

Nunn N, Qian N. The potato's contribution to population and urbanization: evidence from a historical experiment[J]. The Quarterly Journal of Economics, 2011, 126(2): 593-650.

O'Neill J. Modes of individualism and collectivism[M]. Heinemann Educational Publishers, 1973.

Pieroni L, Pompei F. Evaluating innovation and labour market relationships: the case of Italy[J]. Cambridge Journal of Economics, 2007, 32(2): 325-347.

Popp D. Innovation in climate policy models: Implementing lessons from the economics of R&D[J]. Energy Economics, 2006, 28(5): 596-609.

Porter M E. Towards a dynamic theory of strategy[J]. Strategic management journal, 1991, 12(S2): 95-117.

Ruan J, Xie Z, Zhang X. Does rice farming shape individualism and innovation?[J]. Food Policy, 2015, 56: 51-58.

Sakakibara M. The diversity of R&D consortia and firm behavior: Evidence from Japanese data[J]. The Journal of Industrial Economics, 2001, 49(2): 181-196.

Scotchmer S. Standing on the shoulders of giants: cumulative research and the patent law[J]. The journal of economic perspectives, 1991, 5(1): 29-41.

Smith, Bruce D. (1998) The Emergence of Agriculture. Scientific American Library, A Division of HPHLP, New York, ISBN 0-7167-6030-4.

Sokoloff K L, Engerman S L. History lessons: Institutions, factors endowments, and paths of development in the new world[J]. The Journal of Economic Perspectives, 2000, 14(3): 217-232.

Talhelm T, Zhang X, Oishi S, et al. Large-scale psychological differences within China explained by rice versus wheat agriculture[J]. Science, 2014, 344(6184): 603-608.

Temin P. Two views of the British industrial revolution[J]. The Journal of Economic History, 1997, 57(1): 63-82.

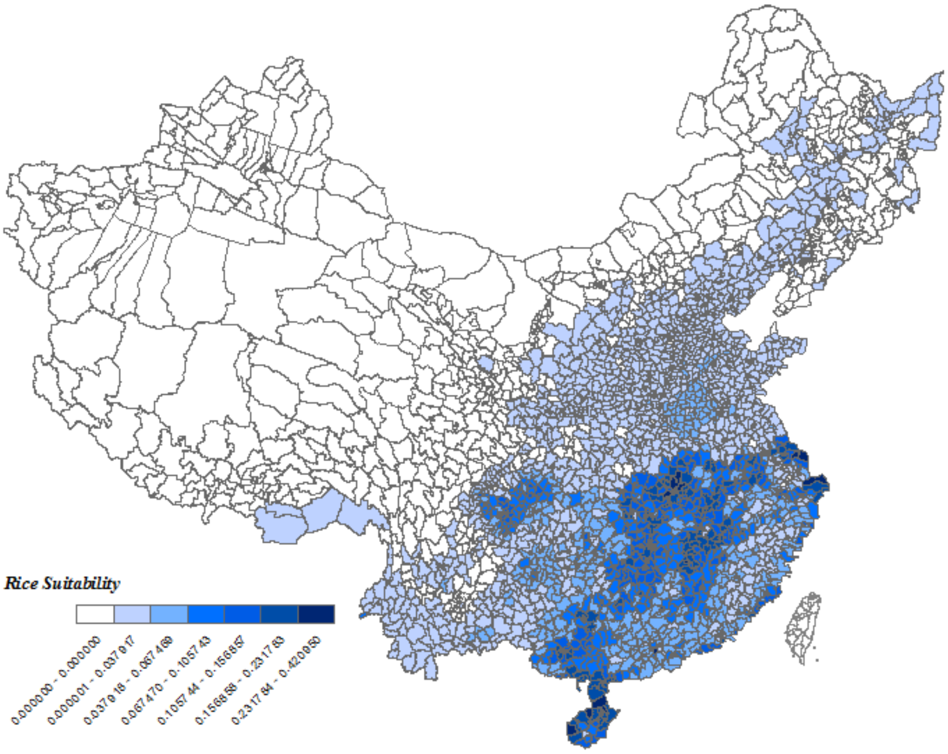
Toivanen O, Väänänen L. Education and invention[J]. Review of Economics and Statistics, 2016, 98(2): 382-396.

Triandis H C. Individualism & collectivism[M]. Westview press, 1995.

Vandello J A, Cohen D. Patterns of individualism and collectivism across the United States[J]. Journal of personality and social psychology, 1999, 77(2): 279.

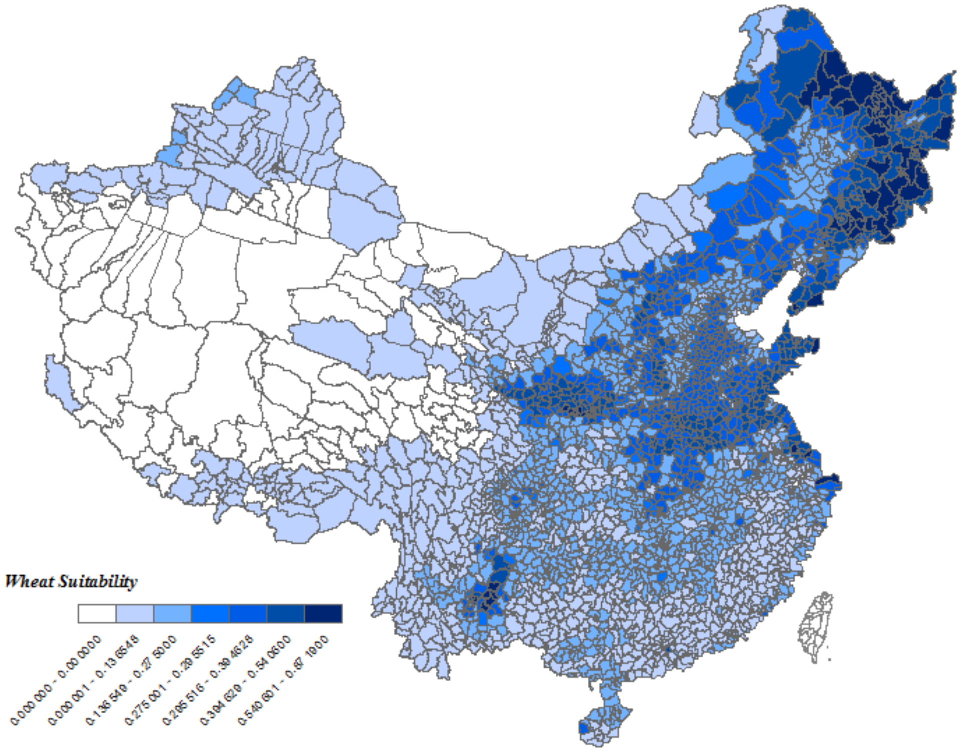
Williams H L. Intellectual property rights and innovation: Evidence from the human genome[J]. Journal of Political Economy, 2013, 121(1): 1-27.

Figure 1: Distribution of the County-level Rice Suitability Value



Notes: The diagram shows the overall level of the strength of rice suitability. Darker regions represent stronger rice suitability. The data are taken from Global Agro-Ecological Zones (GAEZ) FAO.

Figure 2: Distribution of the County-level Wheat Suitability Value



Notes: The diagram shows the overall level of the strength of wheat suitability. Darker regions represent stronger wheat suitability. The data are taken from Global Agro-Ecological Zones (GAEZ), FAO.

Table 1: Analysis using County-Level Data

Dep. Var. = Patents per capita	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Rice suitability	-0.067**	-0.093***	-0.144***				-0.077**	-0.107***	-0.148***
	(-2.25)	(-3.12)	(-4.47)				(-2.57)	(-3.54)	(-4.59)
Wheat suitability				0.058**	0.070**	0.032	0.070**	0.086***	0.046
				(1.96)	(2.35)	(1.03)	(2.32)	(2.88)	(1.48)
Distance to coast			0.028			0.056			0.041
			(0.44)			(0.87)			(0.65)
Elevation			-0.071			-0.042			-0.058
			(-0.87)			(-0.51)			(-0.71)
Precipitation			-0.165**			-0.223***			-0.159**
			(-2.39)			(-3.29)			(-2.30)
Temperature			-0.149*			-0.163*			-0.140
			(-1.65)			(-1.80)			(-1.54)
Std. of temperature			-0.024			-0.015			-0.021
			(-0.84)			(-0.54)			(-0.73)
Land cover			0.175***			0.146***			0.171***
			(6.18)			(5.20)			(6.01)
Latitude			-0.166**			-0.161**			-0.176**
			(-2.15)			(-2.08)			(-2.28)
N	2005	2005	2005	2005	2005	2005	2005	2005	2005
R^2	0.202	0.216	0.244	0.201	0.214	0.236	0.204	0.219	0.244
Province dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES
North-south dummies	NO	YES	YES	NO	YES	YES	NO	YES	YES

Notes: All observations are at the county level. The coefficients are standardized beta coefficients and the intercept estimate is not shown. *t*-statistics are reported in parentheses. *, **and***indicate significance at the 10%, 5% and 1% levels, respectively. North-south China is divided by Huai River/Qinling Mountain line.

Table 2: Analysis using Province-Level Data

Dep. Var. = Patents per capita	(1)	(2)	(3)	(4)	(5)	(6)
Rice suitability	-0.772***		-0.781***	-0.698**		-0.670**
	(-3.20)		(-3.16)	(-2.38)		(-2.32)
Wheat suitability		0.001	0.050		-0.385	-0.338
		(0.00)	(0.34)		(-1.31)	(-1.30)
N	26	26	26	26	26	26
R^2	0.564	0.370	0.567	0.758	0.705	0.783
Baseline controls	NO	NO	NO	YES	YES	YES
North-south dummies	YES	YES	YES	YES	YES	YES

Notes: All observations are at the county level. The coefficients are standardized beta coefficients and the intercept estimate is not shown. *t*-statistics are reported in parentheses. *, **and***indicate significance at the 10%, 5% and 1% levels, respectively. North-south China is divided by Huai River/Qinling Mountain line.

Table 3: Analysis using Prefecture-Level Data

Dep. Var. = Patents per capita	(1)	(2)	(3)	(4)	(5)	(6)
Rice suitability	-0.190**		-0.211**	-0.332***		-0.330***
	(-2.10)		(-2.26)	(-3.88)		(-3.72)
Wheat suitability		0.027	0.060		-0.079	-0.006
		(0.44)	(0.96)		(-1.03)	(-0.08)
N	264	264	264	264	264	264
R^2	0.153	0.139	0.156	0.349	0.313	0.349
Baseline controls	NO	NO	NO	YES	YES	YES
North-south dummies	YES	YES	YES	YES	YES	YES

Notes: All observations are at the county level. The coefficients are standardized beta coefficients and the intercept estimate is not shown. *t*-statistics are reported in parentheses. *, **and***indicate significance at the 10%, 5% and 1% levels, respectively. North-south China is divided by Huai River/Qinling Mountain line.

Table 4: Analysis using Rice Yield and Controlling for the Effect of Agricultural Productivity

Dep. Var. = Patents per capita	(1)	(2)	(3)
Rice yield	-0.131***		-0.141***
	(-4.67)		(-4.90)
Wheat yield		-0.018	-0.057
		(-0.52)	(-1.58)
Farmland	-0.079***	-0.086***	-0.077**
	(-2.59)	(-2.81)	(-2.51)
Machine	-0.008	0.001	0.019
	(-0.28)	(0.01)	(0.53)
Irrigation	0.011	-0.017	0.013
	(0.36)	(-0.55)	(0.43)
Electricity	0.019	0.019	0.019
	(0.95)	(0.92)	(0.94)
Fertilizer	-0.076**	-0.115***	-0.064**
	(-2.44)	(-3.78)	(-1.99)
Pesticide	0.003	-0.001	0.002
	(0.17)	(-0.05)	(0.11)
N	1942	1942	1942
R^2	0.252	0.243	0.253
Province dummies	YES	YES	YES
North-south dummies	YES	YES	YES
Baseline controls	NO	NO	NO

Notes: All observations are at the county level. The coefficients are standardized beta coefficients and the intercept estimate is not shown. *t*-statistics are reported in parentheses. *, **and***indicate significance at the 10%, 5% and 1% levels, respectively. North-south China is divided by Huai River/Qinling Mountain line.

Table 5: Analysis using Chinese General Social Survey (CGSS) Individual- Level Data

Dep. Var. = Belief in Science and Technology	(1)	(2)	(3)	(4)	(5)	(6)
Rice suitability	-7.617***	-7.831***			-7.503**	-7.963**
	(-2.69)	(-2.76)			(-2.15)	(-2.28)
Wheat suitability			0.612	0.592	0.026	-0.030
			(1.61)	(1.56)	(0.06)	(-0.06)
Age		-0.168		-0.157		-0.168
		(-1.49)		(-1.40)		(-1.49)
Age squared		0.176		0.165		0.176
		(1.57)		(1.48)		(1.57)
Gender		-0.001		-0.002		-0.001
		(-0.06)		(-0.10)		(-0.06)
Marital status		0.060***		0.058***		0.060***
		(2.95)		(2.86)		(2.95)
Education		-0.012		-0.012		-0.012
		(-0.53)		(-0.52)		(-0.53)
Income		0.008		0.009		0.008
		(0.38)		(0.40)		(0.38)
House size		-0.015		-0.014		-0.015
		(-0.74)		(-0.73)		(-0.74)
N	3177	3177	3177	3177	3177	3177
R^2	0.087	0.090	0.086	0.089	0.087	0.090
County dummies	YES	YES	YES	YES	YES	YES
North-south dummies	YES	YES	YES	YES	YES	YES
Baseline controls	NO	NO	NO	NO	NO	NO

Notes: All observations are at the county level. The coefficients are standardized beta coefficients and the intercept estimate is not shown. *t*-statistics are reported in parentheses. *, **and***indicate significance at the 10%, 5% and 1% levels, respectively. North-south China is divided by Huai River/Qinling Mountain line.

Table 6: Analysis using Alternative Measure by Rice-wheat Ratio

Dep. Var. = Patents per capita	(1)	(2)	(3)	(4)
Rice-wheat ratio	-0.252***	-0.309***	-0.259***	-0.306***
	(-7.45)	(-8.52)	(-7.72)	(-8.51)
N	2005	2005	2005	2005
R^2	0.222	0.248	0.235	0.263
Province dummies	YES	YES	YES	YES
North-south dummies	NO	NO	YES	YES
Baseline controls	NO	YES	NO	YES

Notes: Following Easterly (2007), we use a unified variable Rice-wheat Ratio defined as the log of the share of rice suitability on wheat suitability, namely, Log[(1+rice suitability*10000)/(1+wheat suitability*10000)] to reveal our main idea. All observations are at the county level. The coefficients are standardized beta coefficients and the intercept estimate is not shown. *t*-statistics are reported in parentheses. *, **and***indicate significance at the 10%, 5% and 1% levels, respectively. North-south China is divided by Huai River/Qinling Mountain line.

Table 7: Controlling for the Effect of GDP per capita, Education, Aging, Migration, Agricultural Cycle, and Religiousness

Dep. Var. = Patents per capita	(1)	(2)	(3)	(4)	(5)	(6)
Rice suitability	-0.119***	-0.134***	-0.156***	-0.130***	-0.139***	-0.149***
	(-3.83)	(-4.27)	(-4.85)	(-4.19)	(-4.43)	(-4.65)
Wheat suitability	0.017	0.003	0.007	0.003	0.004	0.006
	(0.58)	(0.09)	(0.22)	(0.10)	(0.12)	(0.20)
GDP per capita	0.279***					
	(12.54)					
Education		0.249***				
		(9.83)				
% of pop. older than 65			-0.083***			
			(-3.18)			
% of pop. younger than 15				-0.309***		
				(-12.67)		
% of pop. migrate in					0.193***	
					(9.66)	
Religiousness						-0.088***
						(-4.13)
N	1989	1989	1989	1989	1989	1989
R^2	0.312	0.292	0.261	0.314	0.291	0.263
Province dummies	YES	YES	YES	YES	YES	YES
North-south dummies	YES	YES	YES	YES	YES	YES
Baseline controls	YES	YES	YES	YES	YES	YES

Notes: All observations are at the county level. The coefficients are standardized beta coefficients and the intercept estimate is not shown. *t*-statistics are reported in parentheses. *, **and***indicate significance at the 10%, 5% and 1% levels, respectively. North-south China is divided by Huai River/Qinling Mountain line.

Table 8: Analysis using Alternative Mean of Patents Per Capita

Dep. Var. = Patents per capita	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Mean of 2006 to 2010			Mean of 2011 to 2015			Mean of 2001 to 2015		
Rice suitability	-0.122***		-0.127***	-0.121***		-0.129***	-0.126***		-0.134***
	(-3.62)		(-3.77)	(-3.71)		(-3.94)	(-3.81)		(-4.04)
Wheat suitability		0.043	0.055*		0.066**	0.078**		0.067**	0.079**
		(1.32)	(1.69)		(2.12)	(2.50)		(2.10)	(2.50)
N	2005	2005	2005	2005	2005	2005	2005	2005	2005
R^2	0.174	0.169	0.175	0.229	0.225	0.231	0.205	0.201	0.208
Province dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES
North-south dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES
Baseline controls	YES	YES	YES	YES	YES	YES	YES	YES	YES

Notes: All observations are at the county level. The coefficients are standardized beta coefficients and the intercept estimate is not shown. *t*-statistics are reported in parentheses. *, **and***indicate significance at the 10%, 5% and 1% levels, respectively. North-south China is divided by Huai River/Qinling Mountain line.

Table 9: Analysis using Alternative Cereal Crops: Maize

Dep. Var. = Patents per capita	(1)	(2)	(3)	(4)	(5)	(6)
Rice suitability				-0.129^{***}		-0.128^{***}
				(-3.93)		(-3.92)
Wheat suitability					0.109^{***}	0.108^{***}
					(3.03)	(3.03)
Maize suitability	-0.074^{**}	-0.046	-0.102^{***}	-0.076^{**}	-0.161^{***}	-0.134^{***}
	(-2.41)	(-1.48)	(-3.12)	(-2.28)	(-4.23)	(-3.49)
N	2005	2005	2005	2005	2005	2005
R^2	0.202	0.213	0.240	0.246	0.243	0.249
Province dummies	YES	YES	YES	YES	YES	YES
North-south dummies	NO	YES	YES	YES	YES	YES
Baseline controls	NO	NO	YES	YES	YES	YES

Notes: All observations are at the county level. The coefficients are standardized beta coefficients and the intercept estimate is not shown. *t*-statistics are reported in parentheses. *, **and***indicate significance at the 10%, 5% and 1% levels, respectively. North-south China is divided by Huai River/Qinling Mountain line.

Table 10: Analysis using Sub-Sample of North & South China

Dep. Var. = Patents per capita	(1)	(2)	(3)	(4)	(5)	(6)
	Southern China			Northern China		
Rice suitability	-0.116***		-0.127***		-0.116***	-0.111***
	(-2.95)		(-3.14)		(-3.27)	(-3.11)
Wheat suitability		0.019	0.048	0.087**		0.075*
		(0.46)	(1.18)	(2.00)		(1.72)
N	919	919	919	1086	1086	1086
R^2	0.214	0.207	0.215	0.150	0.155	0.158
Province dummies	YES	YES	YES	YES	YES	YES
Baseline controls	YES	YES	YES	YES	YES	YES

Notes: All observations are at the county level. The coefficients are standardized beta coefficients and the intercept estimate is not shown. *t*-statistics are reported in parentheses. *, **and***indicate significance at the 10%, 5% and 1% levels, respectively. North-south China is divided by Huai River/Qinling Mountain line.

Table 11: Exclusion of Districts and Cities

Dep. Var. = Patents per capita	(1)	(2)	(3)	(4)	(5)	(6)
	Exclude Districts			Exclude Cities		
Rice suitability	-0.094^{**}		-0.110^{**}	-0.157^{***}		-0.162^{***}
	(-2.19)		(-2.55)	(-4.47)		(-4.58)
Wheat suitability		0.098^{**}	0.112^{***}		0.029	0.044
		(2.40)	(2.74)		(0.87)	(1.34)
N	1346	1346	1346	1692	1692	1692
R^2	0.170	0.171	0.175	0.260	0.251	0.261
Province dummies	YES	YES	YES	YES	YES	YES
North-south dummies	YES	YES	YES	YES	YES	YES
Baseline controls	YES	YES	YES	YES	YES	YES

Notes: All observations are at the county level. The coefficients are standardized beta coefficients and the intercept estimate is not shown. *t*-statistics are reported in parentheses. *, **and***indicate significance at the 10%, 5% and 1% levels, respectively. North-south China is divided by Huai River/Qinling Mountain line.

Table A1: Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
County-level					
Patents per capita	2005	0.000555	0.001396	0	0.012805
Mean of 2006 to 2010	2005	0.000201	0.000547	0	0.003749
Mean of 2011 to 2015	2005	0.000935	0.002223	0	0.01579
Mean of 2001 to 2015	2005	0.000403	0.000992	0	0.007284
Rice suitability	2005	0.04	0.052867	0	0.204782
Wheat suitability	2005	0.288957	0.14939	0.004512	0.68966
Rice-wheat ratio	2005	-3.59416	2.705505	-8.83893	1.910666
Distance to coast	2005	4.681201	4.104463	0	23.08835
Elevation	2005	5.475215	8.050908	0.000408	51.1386
Precipitation	2005	20.6411	20.50344	0.697368	76
Temperature	2005	13.07139	5.214493	1.2	22.4
Std. of temperature	2005	5.149319	6.988362	0	76.62729
Land cover	2005	12.72779	3.980228	1.351351	22
Latitude	2005	33.54547	6.031466	18.25	50.78
GDP per capita	1989	1.913824	1.76365	0.246046	21.7429
Education	1989	7.523172	1.165558	1.3	11.71
% of pop. older than 65	1989	6.934008	1.494395	3.78	10.38
% of pop. younger than 15	1989	22.97396	4.728384	12.8	34.17
% of pop. migrate in	1989	0.071869	0.083516	0.005142	0.311712
Religiousness	1989	4.119155	12.82459	0	161
Rice yield	1942	0.714934	1.106235	0	7.25334
Wheat yield	1942	0.445895	0.622286	0	7.445
Farmland	1942	2.210718	2.584478	0	25.60606
Machine	1942	0.297979	0.51934	0	6.487
Irrigation	1942	0.259444	3.586632	0	95.64527
Electricity	1942	0.180794	0.227276	0	2.37529
Fertilizer	1942	0.019783	0.262457	0	8.56692
Pesticide	1942	0.714934	1.106235	0	7.25334
Province-level					
Patents per capita	26	0.0005	0.00062	4.45E-05	0.001728
Rice suitability	26	0.036665	0.044786	0	0.169446
Wheat suitability	26	0.203079	0.1316	0.003162	0.461861
Prefecture-level					
Patents per capita	264	0.000575	0.00093	4.57E-06	0.004911
Rice suitability	264	0.037908	0.050003	0	0.234094
Wheat suitability	264	0.230484	0.148302	0	0.699131
Chinese General Social Survey (CGSS)					
Belief in Science	3177	3.479068	1.048397	1	5
Rice suitability	3177	0.042637	0.053759	0	0.200625
Wheat suitability	3177	0.309581	0.173553	0.0404	0.76192
Age	3177	46.58672	15.52089	17	90

Age squared	3177	2411.144	1526.294	289	8100
Gender	3177	0.495751	0.500061	0	1
Marital status	3177	0.807995	0.393939	0	1
Education	3177	4.789739	2.799084	1	11
Household income	3177	4.444491	4.157882	0.1	20
House size	3177	103.7825	58.19171	30	250

Table A2: Data Sources and Definitions of Variables

Variables	Description	Source
	[A] Key variables	
Patents per capita	The patent statistics are the number of granted patents for all categories including patents for inventions, industrial designs and utility models. Patents Per Capita is calculated by dividing patents by population. Patent data is obtained from Patent Explorer database. The population data are taken from China Population Census (2010).	Patent Explorer database; China Population Census (2010)
Rice suitability	We use historical information in the rice agro-ecological suitability as our explanatory variable, defined as the mean of suitability value for rice cultivation in each counties. The data is taken from GAEZ database. The GAEZ database uses complex model to capture temperature, humidity, evaporation, soil quality, slope and other agricultural conditions for rice production. The data are measured on the baseline period from 1960 to 2000.	GAEZ (2000)
Wheat suitability	The same as rice suitability.	GAEZ (2000)
Maize suitability	The same as rice suitability.	GAEZ (2000)
	[B] Geographic Controls	
Distance to coast	The nearest length of the central point of a county to the coastline.	Marine Regions database
Elevation	The mean elevation of a county above sea level.	DIVA-GIS database
Precipitation	The average annual precipitation of a county over the period 1970-2000.	WorldClim database
Temperature	The average annual temperature of a county over the period 1970-2000.	WorldClim database
Std. of temperature	The standard deviation of temperature.	WorldClim database
Land cover	The mean of land cover of each county.	DIVA-GIS database
Latitude	The absolute value of the latitude of each county.	DIVA-GIS database
	[C] Socioeconomic Controls	
GDP per capita	Ratio of GDP to population in year 2010.	China County Statistical Yearbook
Education	Average school years of whole population in year 2000.	China Census Data
% of pop. older than 65	Share of population older than 65 in year 2000.	China Census Data
% of pop. younger than 15	Share of population younger than 15 in year 2000.	China Census Data
% of pop. migrate in	Share of population migrate in from outside in year 2000.	China Census Data
Religiousness	Number of Buddhist temples in each county in year 2006.	World Map database
	[D] Agricultural Production Controls	
Rice yield	Rice yield of a county in year 2002.	Rural Statistical Yearbook
Wheat yield	Wheat yield of a county in year 2002.	Rural Statistical Yearbook
Farmland	Cultivated land of a county in year 2002.	Rural Statistical Yearbook
Machine	Total agricultural machinery power of a county in year 2002.	Rural Statistical Yearbook
Irrigation	Irrigated area of a county in year 2002.	Rural Statistical Yearbook
Electricity	Rural power consumption of a county in year 2002.	Rural Statistical Yearbook
Fertilizer	Fertilizer use of a county in year 2002.	Rural Statistical Yearbook

Pesticide	Pesticide use of a county in year 2002.	Rural Statistical Yearbook