Rice, State, and Income

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Abstract

What fundamentally causes the various levels of per capita income across regions within the same country that share similar political institutions? We present a "rice hypothesis": that the mix of crops grown in different regions explains the variation in economic development. Using sub-national data from China, we demonstrate that rice cultivating regions are significantly wealthier than wheat cultivating regions, controlling for latitude, geography type, natural resources, distance to ports, colonial legacies, and policies. For every 10% increase in cultivated land devoted to rice paddies in the early 1990s, per capita gross domestic product increased by an average of 1.1 yuan/person in the 2000s. Exploiting a geographic regression discontinuity design based on China's Qin Mountains-Huai River line, we show that rice cultivation has a causal effect on per capita income. Causal mediation analysis shows that rice cultivation contributes to per capita income through strong state fiscal capacity rather than social capital. Caution should be exercised when applying the theory outside Asia.

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The city of Dingxi in China had a per capita gross domestic product (GDP) of $642 in 2010, which is equivalent to that of Haiti. In the same country and the same year, the city of Suzhou had a per capita GDP of $17,509, which is equivalent to that of Saudi Arabia and almost 30 times that of Dingxi. How can these starkly different levels of economic development across regions within the same country, where institutions are roughly similar, be explained? This within-country variation is especially puzzling considering that some recent studies in comparative economic development overwhelmingly focus on the role of political institutions (Acemoglu, Johnson and Robinson 2001; Acemoglu, Johnson and Robinson 2002). In this article, we present new evidence that differences in the crops grown in various regions explain the *within-country* variation in contemporary economic development. Specifically, we demonstrate that rice cultivating regions are significantly wealthier than wheat cultivating regions, controlling for latitude, geography type, natural resources, distance to ports, colonial legacies, and policies.

More importantly, we show that rice cultivation contributes to wealth by strengthening state fiscal capacity. Rice cultivation requires water control, and necessitates large-scale labor mobilization and fiscal extraction for irrigation. Based on Marx (1853) and Wittfogel (1957), we contend that the necessity of large-scale cooperation in order to meet these requirements contributed to the establishment of strong states. We argue that this governance pattern persists into the modern era to lead economic development.

We test the "rice hypothesis" using sub-national data from China relying on two empirical approaches. First, ordinary least squares (OLS) regression results show that rice cultivation in the early 1990s is positively correlated with per capita GDP in 2001-2010 while holding everything else constant. Substantively, for every 10% increase in cultivated land devoted to rice paddies in the early 1990s, per capita GDP on average during 2001-2010 increased by 1.1 yuan/person, which amounts to about 1.43 billion yuan ($204 million) per year for the whole country. In addition, rice is estimated to have the fourth-largest effect on per capita income after latitude, distance to ports, and colonial legacies. Its cultivation explains more variation in per capita income than geography type, natural resources, and policies. Our second empirical approach exploits a geographic regression discontinuity (GRD) design based on China's Qin Mountains-Huai River (Qin-Huai) line, which divides the northern wheat and southern rice regions, to estimate the causal effect of rice cultivation on per capita income. The GRD results show that the prefectures right below the line are significantly wealthier than those right above the line.

Causal mediation analysis shows that rice cultivation contributes to per capita income by nurturing strong state fiscal capacity rather than social capital. We further show that, with higher extractive capacity, Chinese local states spend more on infrastructure, which leads to higher per capita GDP. However, we do not find empirical evidence that rice cultivating regions are more corrupt.

We use China data to test the theory because China has a large area that spans different climate zones and offers a large variation in agricultural modes and income levels. The Qin-Huai line that coincides with the border dividing the sub-tropical and temperate zones (and, therefore, the rice and wheat regions) offers a natural experiment with which to estimate the causal effect of rice agriculture on per capita income. A within-country comparison is also advantageous because we can hold some of the important variables, such as political institutions, constant. However, although the findings have high internal validity, we offer caveats at the end of the article about the conditions under which the "rice hypothesis" could be applied beyond China.

We are not aware of others who have examined the link between rice and per capita income, though a long tradition beginning with Marx and Wittfogel links the mode of agricultural production to the form of government. While this article supports the Wittfogel (1957) argument that rice cultivation requires a strong state, our theory differs from Wittfogel's "Oriental Despotism" in that we show that rice has a normatively positive effect. Although we consider our theory to be a variant of the geography hypothesis, our argument differs in that we show a higher level of per capita income in sub-tropical and tropical zones than in temperate zones, whereas the conventional geography hypothesis argues the opposite (Sachs 2001). Another version of the geography hypothesis contends that different historical endowments of plant and animal species created variation in hunting versus farming, and in places where farming dominated, technological innovation took place much more rapidly than in other parts of the world (Diamond 1997). We go further, showing that there is a difference between wheat and rice farming, and that the latter is more favorable to economic development. Our "rice hypothesis" is also fundamentally different from the Acemoglu, Johnson and Robinson (2001) argument that European colonizers imposed property-protecting institutions on their colonies from the outside; we contend that there is an internal agricultural root of economic development within a state.

Studies by Engerman and Sokoloff (1997), Sokoloff and Engerman (2000), and Easterly and Levine (2003) are close to ours, as they test a "crops" hypothesis. They claim that the land endowments of Latin America lent themselves to commodities featuring economies of scale and/or the use of slave and indigenous labor (sugar cane, rice, silver), which historically concentrated power in the hands of the plantation and mining elite. By contrast, the endowments of North America lent themselves to commodities grown on family farms (wheat, maize) and thus promoted the growth of a large middle class in which power was widely distributed (Easterly and Levine 2003, 9). Our study is new in the sense that we focus on a different causal mechanism–state capacity–as the linkage between crops and economic development. In addition, China's high population density made it unnecessary to use slaves, which therefore produced a different development path than in Latin America.

Our findings are consistent with the developmental state literature that underlines the critical function of the state in steering economic development (Johnson 1982; Haggard 1990; Evans 1995; Kohli 2004). However, the developmental state literature rarely explores the origins of developmental states. For example, Cumings (1984) has examined the impact of Japanese colonial rule on the development of a strong bureaucracy in South Korea and Taiwan, while we still know little about how Japan developed a strong bureaucracy in the first place. Our "rice hypothesis" offers a synthesized explanation that links the geography hypothesis and the developmental state thesis and pushes back the causal chain to find a deeper cause of state capacity and economic development. By doing so, we join some recent studies that examine the historical origins of state capacity (Dincecco and Prado 2012) and the relationship between state capacity and economic performance (Dincecco and Katz 2014).

THEORY AND HYPOTHESES

Rice and wheat have long been the most important food crops in the world, including in China. The natural environments that are required for rice and wheat cultivation are distinct. Rice is by nature a semi-aquatic or swamp crop (Latham 1998, 11): most varieties of rice grow in standing water (Bray 1986, 11), so rice cultivation requires *irrigation farming*. By contrast, wheat can grow in dry land, which only needs *rainfall farming*.

Rice cultivation, therefore, necessitates large-scale water control. More than 75% of the world's rice is grown in irrigated fields, and over 90% of the irrigated fields are in East Asia (Latham 1998, 10). As De Crespigny (1971, 33-34) shows, rice cultivating areas almost exactly correspond to irrigated cultivation areas.[1] Major rice fields are recorded to have more than 80% of their cultivated land irrigated. Mass mobilization of labor is needed for the large-scale construction required for irrigation and flood control (Perkins 1969, 8). In China, all commoners were historically expected to participate in hydraulic public services, including irrigation, flood control, and drainage works (Wittfogel 1957, 25).[2] Rice cultivation therefore has two implications for our study–political and psychological.

First, politically, teamwork needs leaders. Political control becomes necessary to manage irrigation and other communal projects (Steward 1949). Hence, the necessity for large-scale labor cooperation requires a strong state consisting of leaders, disciplinarians, and organizers (Wittfogel 1957, 26). The power of hydraulic states extends over society as a whole. As highlighted by Wittfogel (1957, 67-72), a critical feature of a hydraulic state is taxation: universal and direct taxation has been imposed and collected since ancient times. In areas where rice is the major agricultural crop, the government needs to levy a large amount of economic production to support large-scale projects (Wittfogel 1957).

China's historically decentralized fiscal system allows us to examine the effect of agricul-

[1] Irrigated cultivation areas are those in which over 50% of cultivated land is irrigated.

[2] As Bai and Kung (2014) elucidate, the rationale of Mao's agricultural collectivization in 1950s was the effectiveness of collective labor in facilitating the construction of irrigation.

tural divergence on current economic performance by examining sub-national variation in per capita income. In China, before the 1994 tax reform, local governments collected all direct taxes; the central government collected transfers from the local governments, and obtained customs and indirect taxes from large state-owned enterprises (Wong 2000). The level of taxation depended highly on economic structure and the extractive capacity of local governments. Even after the tax reform, after the center collects all the state taxes, the responsibility still falls on the local governments to collect local taxes, such as sales tax, income tax, corporate tax, and land use tax (Wong 2000; Lü and Landry 2014).

Chinese local governments are also responsible for providing public services, which requires financial capacity. In the late Qing dynasty, provincial governments were responsible for providing infrastructure, social order, and social welfare (He 2013, 154). In the contemporary period, public goods provision, such as building roads and schools, is the major task of local governments (Tsai 2007). China's economic growth, similar to that of other East Asian economies, relies heavily on state investment. Scholarly studies have shown a strong causal link between investment and growth in the last three decades in China (Demurger 2001; Lin and Liu 2000).

Second, rice cultivation also has psychological implications. In a recent social psychology study, Talhelm et al. (2014) argue that people from rice provinces in China think more collectively and are more loyal to their friends because rice cultivation requires large-scale cooperation among fellow villagers, and this inter-personal trust was handed down through generations. In the political science literature, Putnam (1993) shows that institutions work better in regions where there is a higher level of social capital, which is measured by interpersonal trust, tolerance, and civic engagement. In the same vein, Levi (1998) argues that trust in government determines citizens' compliance with government polices, which contributes to the effectiveness of governance. In line with this logic, rice cultivation may promote social capital that fosters contemporary economic development.

The discussions above can be summarized into the following three testable hypotheses:

Hypothesis 1: Rice cultivating regions have higher per capita GDP than wheat cultivating regions, ceteris paribus.

Hypothesis 1.1: Rice cultivating regions have higher per capita GDP than wheat cultivating regions because rice cultivation encourages the development of a strong state, which in turn makes economic development more successful.

Hypothesis 1.2: Rice cultivating regions have higher per capita GDP than wheat cultivating regions because rice cultivation nurtures a high level of social capital, which in turn makes economic development more successful.

Finally, it is important to note that all of these are *unintended* consequences of rice growing. As Wittfogel (1957, 19) argued, "The pioneers of hydraulic agriculture, like the pioneers of rainfall farming, were unaware of the ultimate consequences of their choice. Pursuing recognized advantage, they initiated an institutional development which led far beyond the starting point." In addition, rice cannot act on its own; people, after all, construct the economy. The last 60 years of Chinese history show that leaders and the masses are far more important in determining the outcome of the economy: Mao Zedong transformed the country into a Soviet-style command economy, and Deng Xiaoping initiated the transition to a modern market economy. The "rice hypothesis" merely implies that, once given the opportunity, people in rice regions are more capable of leading the economy to prosperity.

ESTIMATING THE EFFECT OF RICE

We focus on estimating the effect of rice cultivation on per capita income in this section and postpone the discussion of causal mechanisms to the next section. Our data are from various sources, including government statistics, geographic information system (GIS), a mass survey, and the stock market. Most government statistics are averaged over ten years to minimize temporal fluctuations or manipulation bias caused by Chinese officials' electoral cycles (Guo 2009; Wallace 2014). All variables are measured at the prefectural level.[3]

We use two estimation strategies. First, a multivariate regression framework is employed to control for alternative hypotheses and estimate the correlation between rice cultivation and per capita income. Multivariate regressions are advantageous in holding observable covariates

[3]China has a four-level government: central, province, prefecture, and county.

constant and including all observations and, therefore, maximizing the external validity of the findings. However, multivariate regressions, without strong identification strategies, cannot successfully tackle omitted variable biases introduced by unobservable covariates or reverse causality caused by endogenous regressors. To attain high internal validity, our second approach is a GRD design based on China's Qin-Huai line that divides northern wheat regions and southern rice regions. Meeting several mild assumptions, comparing units just above and below the Qin-Huai line can yield unbiased estimates of the local average treatment effect (LATE) of rice cultivation on per capita income, while sacrificing external validity. As shown below, the use of the two approaches strikes a balance between external and internal validity and produces the same result: rice cultivation has a positive effect on per capita income.

Ordinary Least Squares Regressions

We first use OLS regressions to fit the following equation to a prefectural-level cross-section data file:

$$LOG\ PER\ CAPITA\ GDP_j = \beta_0 + \beta_1 RICE_j + X_j\Gamma + \epsilon_j, \tag{1}$$

where coefficient β_1 measures the effect of rice cultivation on per capita income, after controlling for the available covariates in X. We measure the key variables as follows.

Dependent Variable. The dependent variable, **LOG PER CAPITA GDP**$_j$, is the natural log transformed per capita GDP of prefecture j. We take the 2001-2010 average of this measure to smooth temporal fluctuations.

Independent Variable. Our main independent variable, $\mathbf{RICE_j}$, is the percentage of cultivated land in prefecture j that is devoted to rice paddies. We collect the data from provincial statistical yearbooks as early as possible; many prefectures have data from the early 1990s. We use early rice data to avoid possible endogeneity problems, and also avoid figures affected by recent advances in irrigation and mechanization. The measure excludes data from Tibet, Xinjiang, and Inner Mongolia, because these are herding regions.

Controls. Prior studies have identified the following factors that affect per capita income.

First, **LATITUDE** is expected to have a positive effect on per capita income according to the geography hypothesis (Montesquieu 1989; Diamond 1997; Sachs 2001; Gallup, Sachs and Mellinger 1999; Hall and Jones 1999). Second, we expect **PLATEAU** (the percentage of area that is covered by plateaus) to have a positive effect on per capita income because landlocked areas surrounded by mountains have great disadvantages in development (Collier 2007, 54-55). Third, **NATURAL RESOURCE** measures whether the prefecture has *any* of the following: oil field, gas field, coal mine, or ore reserve.[4] We also use an alternative way to break down the four types of resources and use four indicators for **OIL**, **GAS**, **COAL**, and **ORE**, respectively.[5] We expect that natural resource wealth has a negative impact on per capita income (Ross 1999). Fourth, **DISTANCE TO PORTS** uses GIS data to calculate the driving distance (in kilometers) from the prefectural center to the nearest major ports.[6] We expect DISTANCE TO PORT's effect to be negative (Collier 2007, 53). Fifth, we create an indicator (**COLONY**) for prefectures that have ever been ceded territories based on Fairbank and Twitchett (1980).[7] Because foreign citizens settled in these concessions, we expect COLONY's effect to be positive (Acemoglu, Johnson and Robinson 2001).[8] Sixth, **POLICY** indicates whether a prefecture is designated a SEZ or COC.[9] We expect POLICY's effect to be positive (Shirk 1993; Naughton 1996). Lastly, **MIGRANTS**–the percentage of inter-province migrants in the total population in a province or prefecture based on the 2000 census–is included to take into consideration that if the causal mechanism is through people, such as social capital, migrants would bring "wheat culture" to

[4]Geo-spatial data for oilfields, gas fields, coal mines, and ore deposits are incorporated from the database of the United States Geological Survey (Karlsen et al. 2001).

[5]An intuition behind the separation is that the value of each mineral varies significantly over time. For instance, while hydrothermal minerals such as gold and silver have been highly valued throughout the history, fossil fuel resources, especially petroleum, have become essential sources of energy and industrial materials only only in the last few centuries.

[6]China's major ports include Shanghai Port, Qinhuangdao Port, Dalian Port, Tianjin Port, Qingdao Port, Lianyungang Port, Guangzhou Port, Zhanjiang Port, and Fuzhou Port.

[7]The following countries have had concessions in China: Russia, Germany, Italy, Japan, Belgium, France, the United States, and Great Britain. Hong Kong, Macau, and Taiwan are not included in the sample.

[8]China has never been completely colonized by foreigners. However, after the First Opium War in 1840, China's late Qing government ceded many territories to foreign powers as a result of a series of unequal treaties. In these concessions, the citizens of foreign countries often had extraterritorial rights and transplanted their own churches, public houses, and other institutions to the Chinese territories.

[9]The SEZs include Shenzhen, Shantou, and Zhuhai in Guangdong Province, Xiamen in Fujian Province, and the whole of Hainan Province. The COCs include Dalian (Liaoning), Qinhuangdao (Hebei), Tianjin, Yantai (Shandong), Qingdao (Shandong), Lianyungang (Jiangsu), Nantong (Jiangsu), Shanghai, Ningbo (Zhejiang), Wenzhou (Zhejiang), Fuzhou (Fujian), Guangzhou (Guangdong), Zhanjiang (Guangdong), and Beihai (Guangxi).

rice regions, or vice versa, and bias the results.[10]

We also include provincial fixed effects to account for unobservable historical, cultural, or leadership variables at the provincial level. Table A23 in the web appendix presents all variables' summary statistics.

[INSERT TABLE 1 HERE]

Table 1 presents the OLS estimates of Equation (1) with standard errors clustered at the provincial level. Column 1 shows the results with the aggregate NATURAL RESOURCE variable and without provincial fixed effects, column 2 with the aggregate NATURAL RESOURCE variable and with provincial fixed effects, and column 3 with alternative natural resource measures and with provincial fixed effects. In all three specifications, RICE's effect on LOG PER CAPITA GDP is significantly positive. Substantively, using the estimate in column 2 as a baseline, for every 10% increase in cultivated land devoted to rice paddies in the early 1990s, per capita GDP increased an average of 1.1 yuan/person in 2001-2010 , which amounts to about 1.43 billion yuan ($204 million) per year for the whole country.

We find some support for the geography hypothesis, that LATITUDE affects per capita income. Without fixed effects, LATITUDE's effect is significantly positive, indicating that prefectures in temperate zones are wealthier than those in the tropics. However, this effect becomes indistinguishable from zero after controlling for provincial fixed effects, which might absorb sub-national variations between provincial boundaries.

There is no support that geography type, measured by PLATEAU, has any effect on per capita income. The effect is small and insignificant in all specifications.

We also find no evidence that natural resource wealth either obstructs or supports economic development. Whether we use the aggregate or disaggregate measures, natural resource wealth's effect is indistinguishable from zero using any conventional confidence intervals.

There is weak support for the importance of DISTANCE TO PORTS, which has a significantly positive effect without provincial fixed effects but becomes insignificant after controlling

[10] One fact may alleviate this concern: most migrants in China are moving from west to east rather than from north to south (Chan, Henderson and Tsui 2008); while the latter mixed wheat and rice, the former just creates mobility within wheat or rice regions. Holding the share of migrants constant will further decrease the bias.

for province dummies.

We find strong support that legacies of colonial policies still influence current economic development: prefectures that were ceded to foreign powers in the late Qing Dynasty are significantly richer. COLONY's effect is significant regardless of whether we control for provincial fixed effects. Substantively, former colonies enjoy a 1.6 yuan/person higher per capita GDP than non-colonies. However, the causal mechanism is less clear. It might be that colonizers set up strong institutions that persist to the present to determine economic performance, as argued by Acemoglu, Johnson and Robinson (2001), or that colonizers chose to settle in wealthier cities in the first place, and historical wealth influences present wealth. Clarifying the causal link between colonial legacies and economic performance is beyond the scope of this study and better left for future research.

There is also no evidence that Deng Xiaoping's early reform policies still affect development outcomes in the 21st century. POLICY, an indicator for SEZs and COCs, has an insignificant effect on per capita income. We suspect that it might be due to the inclusion of COLONY, which is highly correlated with POLICY, because many of the SEZs and COCs are former colonies. Table A1 in the web appendix shows that POLICY's effect becomes significantly positive at the 10% level after excluding COLONY.

Our control variable MIGRANTS is significantly positive for the obvious reason that wealthier cities either attract more migrants or that migrants make cities wealthier by providing cheap labor. The importance of including this control is that if RICE determines per capita income through people, such as social capital, even when we control for inter-province migrants, there is still a relationship between rice cultivation and economic performance.

To compare the *relative* importance of each explanatory variable, we use the η^2 method to measure the proportion of the total variance in the dependent variable that is attributed to an effect. The last column in Table 1 presents the η^2 of each variable. RICE has the fourth-largest effect after LATITUDE, DISTANCE TO PORTS, and COLONY. RICE explains more variation in per capita income than PLATEAU, NATURAL RESOURCE, and POLICY. Both substantively and statistically, the results support Hypothesis 1.

Geographic Regression Discontinuity Design

We exploit a GRD design to estimate the LATE of rice cultivation on per capita income. The GRD design is based on China's Qin-Huai line that divides northern wheat regions and southern rice regions. The Qin-Huai line, which connects the Qin Mountains in the west and the Huai River in the east, reaches eastward from Tibet to the Pacific. As Perry (1980, 25) showed, "the Huai River has formed the demarcation line between rice-producing South China and the wheat-growing North." The line, located around 32° N latitude, also coincides with the 30th parallel north, which divides temperate climates in the north from sub-tropic climates in the south. Ideally for this study, the different climates on different sides of the Qin-Huai line created natural environments that were favorable to wheat cultivation in the north and rice cultivation in the south.

[INSERT FIGURE 1 HERE]

Figure 1 presents a map of China in which dark color represents prefectures that devoted more than half of their cultivated lands to rice paddies and light color areas dedicated more than half of their cultivated lands to non-rice products (primarily wheat) in the early 1990s. The Qin-Huai line clearly divides these two regions, which rarely shift. As Perkins (1969, 41) shows, "Most of the regions where rice is an important crop today were major rice products a thousand years ago." This provides one of the most important foundations for a successful regression discontinuity (RD) design: exposure to treatment (rice cultivation) was not due to self-selection, which would likely produce a large source bias.

Figure 2 shows prefectures by RICE, the percentage of cultivated lands devoted to rice paddies, and the geo-coded distance from prefectural centers (in degrees latitude) to the Qin-Huai line, set at 32° N latitude. For this natural experiment, the "treatment" is exposure to rice cultivation as the major agricultural activity in a prefecture and the "control" condition is exposure to non-rice cultivation, such as wheat. The forcing variable is latitude. A linear regression estimated within a 2.92° window, the "optimal" bandwidth estimated by the data-driven method proposed by Imbens and Kalyanaraman (2011), on either side of the Qin-Huai line estimates a jump of 42.55% (s.e. clustered by latitude=5.18) in RICE.[11] This jump at the cutoff point provides the basis for identifying the causal effects of being in the rice versus the wheat region.

[INSERT FIGURE 2 HERE]

Both Figures 1 and 2 show that the jump is not from zero to one, that is, from complete rice cultivation to complete wheat cultivation, indicating "fuzziness" around the cut point. Hence the appropriate methodology should be a "fuzzy" RD design (Hahn, Todd and Van der Klaauw 2001; Imbens and Lemieux 2008). A fuzzy RD design, a special case of a "sharp" RD design, applies when a cutoff probabilistically, rather than deterministically, assigns units to treatment or control groups. As with the sharp design, the rationale is that the exogenous nature of the Qin-Huai line means that the units just to its north are likely to be similar to those just to its south in all ways except for treatment exposure likelihood and post-treatment outcomes, creating a "local" quasi-experiment. Given the discontinuous jump in the probability of exposure to rice cultivation, we can identify the effect of rice cultivation for prefectures defined by their latitudes (the forcing variable) at the cutoff point as long as two assumptions hold. First, expected values of "potential outcomes" under treatment and control are smooth around the cutoff point. Second, in the immediate neighborhood of the cutoff point, treatment status is unconfounded relative to the outcomes of interest, conditional on the forcing variable. When these conditions hold, as Hahn, Todd and Van der Klaauw (2001) show, there is a close analogy between how the treatment effect is defined in the fuzzy RD design and in the "Wald" formulation of the treatment effect in an instrumental variables setting. The instrument is an indicator variable for whether the prefecture is above or below the Qin-Huai line. The treatment, rice cultivation, is an endogenous regressor. Treatment effects can then be estimated using a two-stage least-squares (2SLS), with standard errors clustered by latitude providing the appropriate basis for inference (Hahn, Todd and Van der Klaauw 2001).

There are two remaining issues before estimating the model. First, we must choose the size of the bandwidth within which to fit the model. Second, we need to decide on a way to

[11] Table A2a in the web appendix provides the full results.

model the smooth relationship between the forcing variable and outcomes. The choices reflect the crucial bias-variance tradeoff in RD designs.[12] The literature provides two alternative approaches to striking this balance. One, proposed by Imbens and Kalyanaraman (2011), is a data-driven method to choose an asymptotically "optimal" bandwidth and local regression estimator. This approach minimizes the expected prediction error at the cutoff point and exhibits desirable asymptotic convergence properties. The second approach, recommended by Green et al. (2009), is to fit high-order polynomial regressions in a wide window. As evaluated by Green et al. (2009), both approaches perform well.

Below, we estimate the effect of RICE on LOG PER CAPITA GDP using the following two strategies: (1) the Imbens-Kalyanaraman asymptotically optimal bandwidth[13] and (2) a bandwidth twice the "optimal" bandwidth with a high-order polynomial specification search strategy recommended by Green et al. (2009).

We use 2SLS to fit the following equation to the prefectural-level cross-section data file:

$$\begin{aligned} LOG\ PER\ CAPITA\ GDP_j = \beta_0 &+ \beta_1 RICE_j \\ &+ \beta_2 DISTANCE_j \\ &+ \beta_3 SOUTH_j \times DISTANCE_j \\ &+ \phi higher\ order\ terms_j + \epsilon_j, \end{aligned} \tag{2}$$

where LOG PER CAPITA GDP$_j$ is the log-transformed (2001-2010 average) per capita GDP in prefecture j, and $RICE_j$ is an endogenous variable measuring the extent to which prefecture j devoted its cultivated land to rice paddies. We use SOUTH, an indicator for whether a prefecture is below the Qin-Huai line, as an excluded instrument for RICE. $DISTANCE_j$

[12] The larger the bandwidth, the more units that are further away from the Qin-Huai line are included in the estimation. This would over-estimate the effect because the local quasi-experiment induced by the discontinuity only applies to prefectures in the vicinity of the Qin-Huai line, and including prefectures away from the line drags the regression line away from the outcomes of prefectures near the line. This is important, as there is a huge difference between localities in the furthest south, such as Guangdong, and furthest north, such as Heilongjiang. However, a narrow bandwidth will produce imprecise estimates and less informative results as well.

[13] This method is implemented in Stata 13 with the `rdob` package provided by Imbens. Please see http://faculty-gsb.stanford.edu/imbens/RegressionDiscontinuity.html (Accessed June 17, 2014).

is the geo-coded perpendicular distance (in degrees latitude) from the prefectural center to the Qin-Huai line. β_1 is the estimated effect of RICE on LOG per capita GDP, and according to Hypothesis 1, $\beta_1 > 0$.

[INSERT FIGURE 3 HERE]

Figure 3 presents the graphic analysis of Equation (2) with the optimal bandwidth, and Table 2 quantifies the results with the optimal and wider bandwidths.[14] As both the graph and table show, RICE has a significantly positive effect on LOG PER CAPITA GDP, and the effect does not vary much over the different bandwidths. In sum, both the multivariate regressions and the GRD design results support Hypothesis 1.

[INSERT TABLE 2 HERE]

Figure 4 illustrates the stability of the results reported in our baseline specification as we vary the bandwidth. The figure indicates that we consistently find a point estimate of about 0.02 across bandwidths, and that these estimates are generally a bit shy of significance at the 5% level, two-tailed.

[INSERT FIGURE 4 HERE]

Robustness Checks

Despite the strong internal validity of RD designs, several methodological issues arise in geographical contexts. Following the recommendations of Keele and Titiunik (2015), we conduct the following two auxiliary analyses to check the robustness of the GRD findings.

First, a valid GRD design, similar to a non-spatial RD design, requires that the pretreatment covariates of treated and control units are comparable. Keele and Titiunik (2015, 149) suggest providing evidence that pretreatment covariates become more and more similar as the distance to the border decreases. We conduct simple t-tests of PLATEAU, NATURAL RESOURCE,

[14]The first-stage results are presented in Table A3 in the web appendix.

DISTANCE TO PORTS, COLONY, and POLICY between rice and wheat regions within different latitude windows and find that as the window narrows there is no significant difference between these two regions on these covariates.[15]

Second, as Keele and Titiunik (2015, 149) argue, compound treatments are common in GRD designs. This problem arises when a geographic border overlaps with an administrative border, so it poses challenges for identifying the independent effect of the geographic border. Keele and Titiunik (2015, 149) hence suggest restricting the analysis, if at all possible, to areas around the border where other important geographically defined institutional units are kept constant on either side of the border. So one strategy to isolate the treatment is to compare prefectures within the same province. Because provinces have considerable autonomy in making local policies (Shirk 1993; Montinola, Qian and Weingast 1995), it is reasonable to assume that some important political, policy, and economic variables are held constant within a province. Jiangsu Province is an ideal case for such a test because it offers enough prefectures on either side of the Qin-Huai line. A t-test of LOG PER CAPITA GDP on either side of the Qin-Huai line in Jiangsu Province shows that the difference is statistically significant (diff.=-0.941, s.e.=0.323).[16]

CAUSAL MECHANISMS

We have shown strong evidence that rice cultivation affects per capita income. However, we still know little about the causal mechanisms.

A simple answer would be the price mechanism that rice is a more expensive and thus more profitable crop. As Figure A1 in the web appendix illustrates, the price of rice was generally higher than that of wheat in China throughout the 2000s, and the gap has increased over time. Nonetheless, the price channel is not likely to play the major role in income divergence. First, crop price also reflects the cost of cultivation, not just the market value and profit margin of a certain crop. Various evidence points out that rice production costs more than other crops. As

[15]Table A4 in the web appendix shows the full results.
[16]Table A5 in the web appendix presents the full results.

Jin et al. (2002) show, rice has the lowest total factor productivity in China, which indicates that it requires more labor and capital inputs than other crops such as wheat and maize. The massive migration of the rural population to urban areas increased labor costs in the agricultural sector in China, and this has been a particular burden to relatively labor-intensive rice farming (Peng et al. 2009). Furthermore, according to Tong, Hall and Wang (2003), rice cultivation has involved more extensive usage of fertilizers compared to wheat production. More importantly, it is widely believed that the manufacturing industry, not agricultural activities, leads to income gaps across Chinese cities in the recent period. Below, we use causal mediation analysis to examine several potential mechanisms and show that the results support strong state fiscal capacity as a viable link between rice and wealth.

Imai et al. (2011, 767-768) define a causal mechanism "as a process whereby one variable T causally affects another Y through an intermediate variable or a mediator M that operationalizes the hypothesized mechanism." And they show that "identification of causal mechanisms can be formulated as a decomposition of a total causal effect into direct and indirect effects." Based on the potential outcomes framework (Rubin 1974), Imai et al. (2011, 769) define indirect effects or *causal mediation effects* for each unit i as follows:

$$\delta_i(t) \equiv Y_i(t, M_i(1)) - Y_i(t, M_i(0)), \tag{3}$$

for each treatment status $t = 0, 1$. δ represents the indirect effects of the treatment on the outcome *through the mediating variable*. As shown in Imai et al. (2011, 769), it equals the change in the outcome corresponding to a change in the mediator from the value that would be realized under the control condition, i.e., $M_i(0)$, to the value that would be observed under the treatment condition, i.e., $M_i(1)$, holding the treatment status at t. By fixing the treatment and changing only the mediator, causal mediation analysis eliminates all other causal mechanisms and isolates the hypothesized mechanism.

Imai et al. (2011) provide a general algorithm and statistical software for estimating causal mediation effects and a method for assessing the sensitivity of conclusions to the potential violations of a key assumption. Specifically, we are interested in estimating the average causal mediation effects (ACME) $\bar{\delta}(t)$ of a hypothesized mechanism (M) that links rice cultivation (T) and per capita GDP (Y).

There are two hypothesized mechanisms. Hypothesis 1.1, based on Marx (1853) and Wittfogel (1957), states that rice cultivation requires intensive water control and large public projects, which contribute to state building. And according to the developmental state literature, a strong state drives the country's economic development (Johnson 1982). The literature especially emphasizes a state's fiscal capacity to collect revenue for large construction (Wittfogel 1957).[17] Following Besley and Persson (2009, 2010), we measure the local state's fiscal capacity (**STATE FISCAL CAPACITY**) using the (7-year average) share of tax revenue in the total GDP of a prefecture.[18] A higher percentage indicates a stronger capacity to extract tax revenue from the society.

Hypothesis 1.2, based on the social psychology (Talhelm et al. 2014) and social capital (Putnam 1993) literatures, contends that rice cultivation, which requires large-scale cooperation, nurtures a high level of social capital that is conducive to economic development. We measure social capital using Putnam's (1993) three indicators: **TRUST** (**PERSONAL** and **POLITICAL**), **TOLERANCE**, and **CIVIC ENGAGEMENT**. We draw data from the China Survey, which is a national probability sample survey that was designed by a group of leading survey researchers. It was coordinated by Texas A&M University and implemented by the Research Center for Contemporary China at Peking University in 2008.[19] Section III in the web appendix discusses details of the measures.

Causal mediation analysis shows that only STATE FISCAL CAPACITY has a positive, significant ACME at the 0.1 level; none of the other mechanisms' ACME is distinguishable from zero.[20] The average effect of the treatment variable (an indicator for prefectures with

[17]State capacity is a sophisticated concept that includes multiple dimensions, including (1) military capacity, (2) bureaucratic administrative capacity, and (3) the quality and coherence of political institutions, according to Hendrix (2010). However, as Hendrix (2010) shows, tax capacity is one of the most theoretically and empirically justified approaches to modeling state capacity.

[18]The data are from the Ministry of Finance's Statistical Reports of All Prefectures, Cities, and Counties (*Quanguo dishixian caizheng tongji ziliao*). We use the 2001-2007 average, because the reports stopped reporting the data after 2007.

[19]For more information about the "China Survey," please see `http://thechinasurvey.tamu.edu` (Accessed June 17, 2014).

[20]The analyses were implemented in Stata 13 using Hicks and Tingley's (2011) `mediation` package.

RICE>50%) on the outcome (LOG PER CAPITA GDP) that operates through the mediator (STATE FISCAL CAPACITY) is 0.105 (90% confidence interval: [0.010,0.200]). The estimated *direct* effect of RICE on LOG PER CAPITA GDP not through STATE FISCAL CAPACITY is indistinguishable from zero, and RICE is estimated to have explained over 90% of the total effect, implying that state fiscal capacity is the dominant mechanism connecting rice cultivation and wealth.[21]

Sensitivity analysis (Table A15 in the web appendix) shows that the results should be considered strong because a confounder needs to explain more than 60% of the remaining variance in both STATE FISCAL CAPACITY and LOG PER CAPITA GDP for the ACME to lose statistical significance.

However, one question remains: how does a strong state lead to economic development? The developmental state literature suggests that a state that prioritizes economic development invests massively in infrastructure building that boosts employment and economic growth. Examples include South Korea's Heavy-Chemical Industry Drive in the 1970s under Park Chung Hee (Cheng, Haggard and Kang 1998) and China's investment-driven growth in the last three decades (Demurger 2001; Lin and Liu 2000).

The data support this argument. A causal mediation analysis using a dichotomous STATE FISCAL CAPACITY as the treatment, **INFRASTRUCTURE SPENDING** (measured as the 2001-2006 average share of infrastructure spending in the total fiscal spending or infrastructure spending per capita) as the mediator[22], and LOG PER CAPITA GDP as the outcome shows that INFRASTRUCTURE SPENDING has a significantly positive ACME at the 0.05 level.[23]

The developmental state literature also suggests that this state-led development model inevitably causes corruption and rent seeking, because large businesses are highly connected with the government (Kang 2002). We use three variables to measure state-business relations and corruption. First, we construct **CONNECTEDNESS**–the percentage of publicly traded firms

[21]Tables A7, A9, A11, A13, and A14 in the web appendix present the full results.

[22]The data are from Ministry of Finance's Statistical Reports of All Prefectures, Cities, and Counties (*Quanguo dishixian caizheng tongji ziliao*). We use the 2001-2006 average, because the reports stopped reporting the data after 2006.

[23]Tables A16 and A18 in the web appendix show the causal mediation analysis results, and Tables A17 and A19 the sensitivity analysis results.

that had at least one former government official on their board of directors in a prefecture in 2010–to measure state-business relations. The rationale is based on the political connections literature, which argues that firms hire former politicians to gain political bargaining power vis-à-vis the government and seek rents (Eggers and Hainmueller 2009; Fisman 2001).[24] Second, we measure **PERCEIVED CORRUPTION** using a question in the China Survey asking respondents to evaluate the level of corruption in the locality. Third, we measure **EXPERIENCED CORRUPTION** using a question in the China Survey probing whether the respondent had experienced any corruption. Using each of these three variables as a mediator, we find no evidence that rice regions are more corrupt.[25]

In sum, the causal mediation analysis supports Hypothesis 1.1. There is, however, no strong evidence for the cultural argument. And our complete causal chain from rice to development is as follows:

$$\text{Rice cultivation} \Rightarrow \text{State fiscal capacity} \Rightarrow \text{Infrastructure spending} \Rightarrow \text{per capita GDP.}$$

CONCLUSION

What fundamentally determines the wealth of nations has been one of the most long-lasting questions that haunts social scientists since Adam Smith, Karl Marx, and Max Weber. Is it geography, institutions, or religion? In this article, we propose a "rice hypothesis" of comparative development that different crops lead to variable levels of state fiscal capacity, which in turn determine per capita income. Using sub-national data from China, we show that rice cultivating regions are significantly wealthier than wheat cultivating regions, controlling for latitude, geography type, natural resources, distance to ports, colonial legacies, and policies. On average, a 10% increase in cultivated land devoted to rice in the 1990s yielded a 1.1 yuan/person increase in per capita GDP 20 years later. Exploiting a GRD design that is based on China's Qin-Huai line, we demonstrate that the effect of rice on per capita income is causal. Using causal mediation analysis, we further show that state fiscal capacity, rather than social capital,

[24]Table A20 in the web appendix discusses how this variable is constructed.
[25]Tables A20-A22 in the web appendix present the full results.

is the mechanism linking rice and income. Rice cultivating regions require large water-control projects that necessitate strong state fiscal capacity, and with strong fiscal capacity, local states increase spending on infrastructure, which leads to higher per capita GDP.

A couple of caveats are in order. First, what we have shown is a very specific model of development that is driven by investment with strong government intervention. The "East Asian Miracle" that relies on heavy investment and strong state intervention has produced rapid economic growth in Japan, South Korea, Taiwan, Singapore, and now China and Vietnam. However, if we put aside the numbers and examine instead what Paul Krugman calls the "nature" of economic growth (Krugman 1994, 65), the East Asian model has also come with the inevitable costs of inefficiency, crony capitalism, and the sacrifice of short-run consumer interests. Japan's "lost decades" and China's recent slowdown also cast doubt on the sustainability of such a development model.

Second, more importantly, although our theory can explain an economy that affects more than one-fifth of the world's population, one must take caution when generalizing our "rice hypothesis" outside Asia. The "rice hypothesis" explicitly requires rice paddies to represent a sizable proportion of a country's cultivated land, and yet almost all of the major rice producers are in Asia.[26] While our theory might explain cross-national and sub-national variations in income among Asian countries, it falls short of providing strong explanatory power for countries that grow crops other than rice, such as maize in America and Africa or cotton in the Middle East. However, we are not proposing "Asian exceptionalism;" our core argument that emphasizes the role of the state in economic development is generalizable to many developing countries that need to overcome their "backwardness" and leap stages of development to achieve prosperity (Gerschenkron 1962).

Finally, our study opens several avenues of future research in exploring the deep roots of state capacity and economic development. Whereas warfare was the core factor in modern state capacity in the European context (Tilly 1975; Besley and Persson 2010; Dincecco and Prado 2012; Gennaioli and Voth forthcoming), state formation in Asia did not involve extensive con-

[26]The top ten rice producers are China, India, Indonesia, Vietnam, Thailand, Bangladesh, Burma, Philippines, Brazil, and Japan. Please see http://faostat.fao.org/site/339/default.aspx (Accessed June 24, 2014). And East Asian countries account for 90% of irrigated rice cultivation (Latham 1998, 10).

flicts with neighboring states. While our study points out one possible explanation of variation in state capacity in Asia, seeking answers to why paths to state development had to be different in Europe and Asia will contribute to our understanding of the "divergence" in the establishment of state capacity between Europe and China (Pomeranz 2000; Rosenthal and Wong 2011; Parthasarathi 2011).

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Table 1: The Effect of Rice Paddies on Log per capita GDP (OLS Estimates)

Variable	**Coeff.** (Clustered S.E.)	**Coeff.** (Clustered S.E.)	**Coeff.** (Clustered S.E.)	η^2
RICE (%)	0.004^{**}	0.007^{***}	0.008^{***}	0.020
	(0.002)	(0.002)	(0.002)	
LATITUDE (degree)	0.036^{***}	0.058	0.056	0.060
	(0.008)	(0.047)	(0.048)	
PLATEAU (%)	0.003	−0.010	−0.011	0.004
	(0.002)	(0.007)	(0.007)	
NATURAL RESOURCE (0,1)	0.072	0.066	–	0.003
	(0.068)	(0.061)		
OIL (0,1)	–	–	0.041	
			(0.094)	
GAS (0,1)	–	–	0.076	
			(0.106)	
COAL (0,1)	–	–	0.073	
			(0.072)	
ORE (0,1)	–	–	−0.036	
			(0.048)	
DISTANCE TO PORTS (km)	0.000^{*}	0.000	0.000	0.029
	(0.000)	(0.000)	(0.000)	
COLONY (0,1)	0.486^{***}	0.481^{***}	0.485^{***}	0.023
	(0.106)	(0.126)	(0.119)	
POLICY (0,1)	0.166	0.162	0.184	0.003
	(0.126)	(0.124)	(0.119)	
MIGRANTS (%)	0.046^{***}	0.042^{***}	0.042^{***}	
	(0.011)	(0.011)	(0.011)	
PROVINCE F.E.	NO	YES	YES	
INTERCEPT	8.144^{***}	8.019^{***}	8.158^{***}	
	(0.350)	(2.199)	(2.230)	
N	277	277	277	
R^2	0.487	0.582	0.582	

Notes: This table presents the OLS estimates of Equation (1) using a prefectual cross section. The dependent variable is the 2001-2010 average LOG PER CAPITA GDP. RICE is the percentage of sown land devoted to rice paddies in the early 1990s. LATITUDE is the geo-coded latitudes (in degree) of prefectural centers. PLATEAU is the percentage of a prefecture's area covered by plateaus. NATURAL RESOURCE is a dummy variable for prefectures that have any of the following: oil field, gas field, coal mine, or ore field. OIL, GAS, COAL, and ORE are all dummy variables indicating whether the prefecture has any of these resources. DISTANCE TO PORTS is the geo-coded distance (in km) from the prefectural center to the nearest major ports. COLONY is an indicator for prefectures that were ceded territories in the late Qing period. POLICY is an indicator for prefectures that are designated SEZs or COCs. MIGRANTS is the percentage of inter-province migrants among the whole population from the 2000 census. η^2 measures the proportion of the total variance in the dependent variable that is attributed to an effect. Standard errors clustered at the provincial level are reported in parentheses. All of mainland China's prefectures are included except those in Tibet, Xinjiang, and Inner Mongolia. p-values are based on a two-tailed test: $*p < 0.1$,$**p < 0.5$, $***p < 0.01$.

Table 2: The Effect of Rice Paddies on Log per capita GDP (2SLS Estimates)

Variable	**Coeff.** (Clustered S.E.)	**Coeff.** (Clustered S.E.)
RICE	0.042^{*}	0.047^{**}
	(0.025)	(0.024)
DISTANCE	-0.724	-0.937^{*}
	(0.509)	(0.538)
SOUTH×DISTANCE	0.519	0.704
	(0.423)	(0.504)
DISTANCE^2	-	-0.021
		(0.024)
DISTANCE^3	-	0.009^{*}
		(0.005)
INTERCEPT	7.080^{*}	6.744^{***}
	(1.518)	(1.440)
N	112	194
χ^2	5.700	12.030
Bandwidth	3.680	7.400

Notes: This table presents the 2SLS estimates of Equation (2) using a prefectural cross section. The dependent variable is the 2001-2010 average LOG PER CAPITA GDP. RICE is the percentage of sown land devoted to rice paddies in the early 1990s. DISTANCE is the geo-coded perpendicular distance from the prefectural center to the Qin-Huai line. SOUTH, the excluded instrument, is an indicator for prefectures south of the Qin-Huai line. Standard errors clustered by latitude are reported in parentheses. 3.680 is the Imbens-Kalyanaraman "optimal" bandwidth. p-values are based on a two-tailed test: $*p < 0.1, **p < 0.5, ***p < 0.01$.

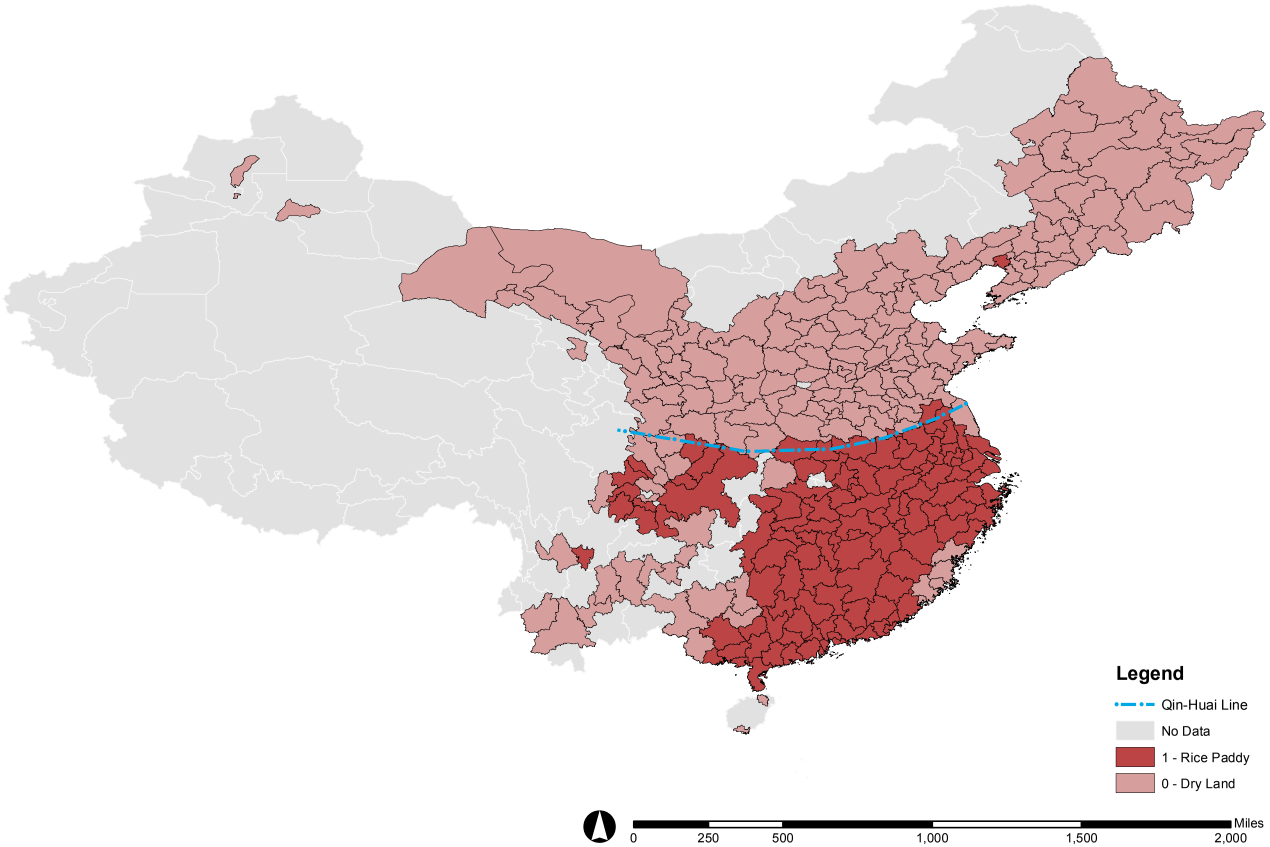

Figure 1: Mapping Rice Paddies

Notes: The darker color indicates prefectures that devoted more than half of their cultivated land to rice paddies in the early 1990s, and the lighter color denotes those that dedicated less than half. Most prefectures in the three major herding provinces, Tibet, Xinjiang, and Inner Mongolia, are not shaded. The rice paddy data are from provincial statistical yearbooks.

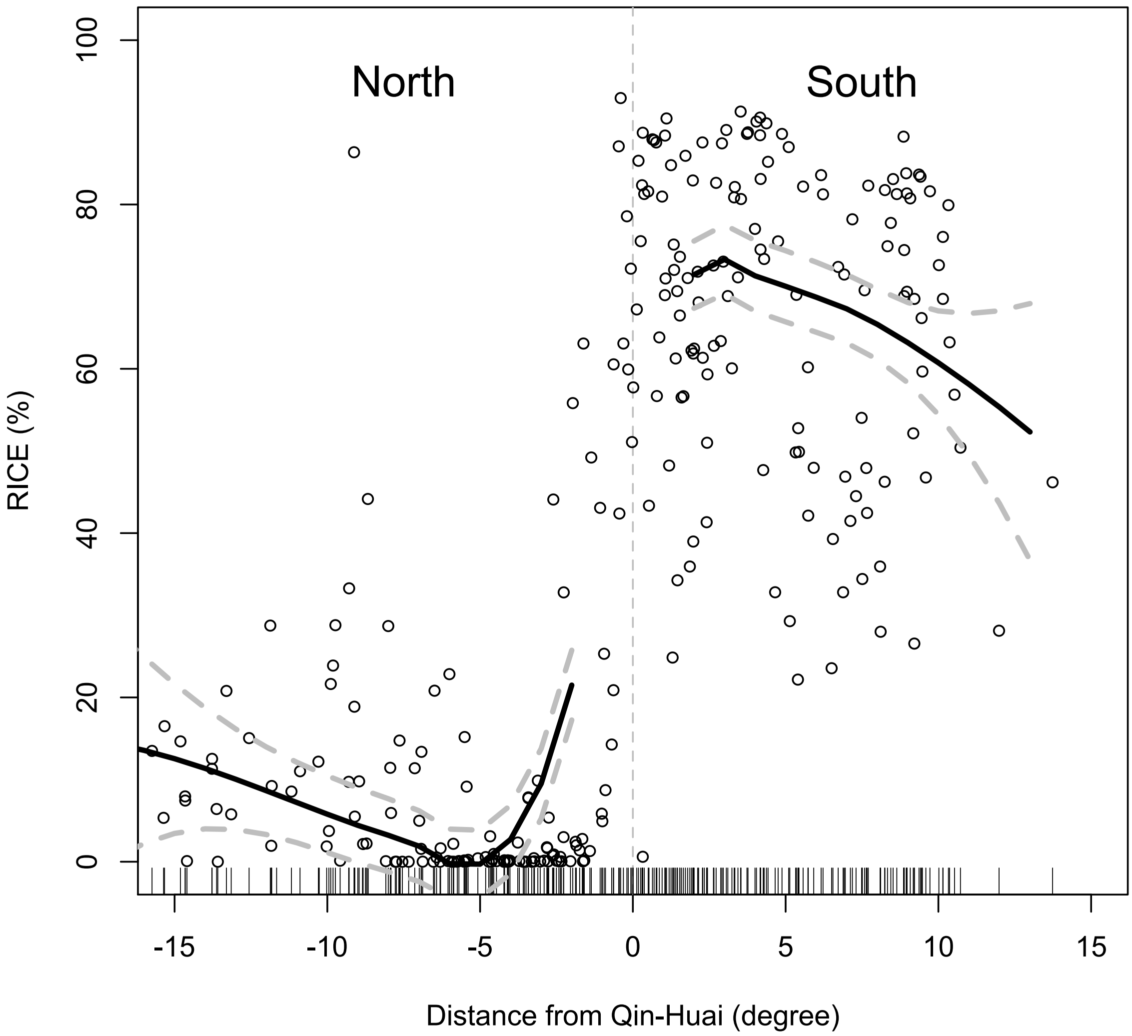

Figure 2: Rice Paddies by Latitude (Centered at the Qin-Huai Line)

Notes: The figure plots RICE, the percentage of a prefecture's cultivated land devoted to rice paddies, over LATITUDE, with LATITUDE centered at 32° N latitude. The lines are from local linear regression smoother fits to the prefectures. The local linear regression smoothers are fit on either side of the cut point, demarcated by the vertical line. Positive distances represent south, negative distances present north. The rug indicates the actual distribution of prefectures in the sample. The grey dotted line represents the 95% confidence interval. The jump of RICE at the cut point is estimated to be 42.55% (s.e. clustered by latitude=5.18) with the "Imbens-Kalyanaraman optimal" bandwidth of 2.92° and a rectangle kernel. Table A2a in the web appendix provides the full results.

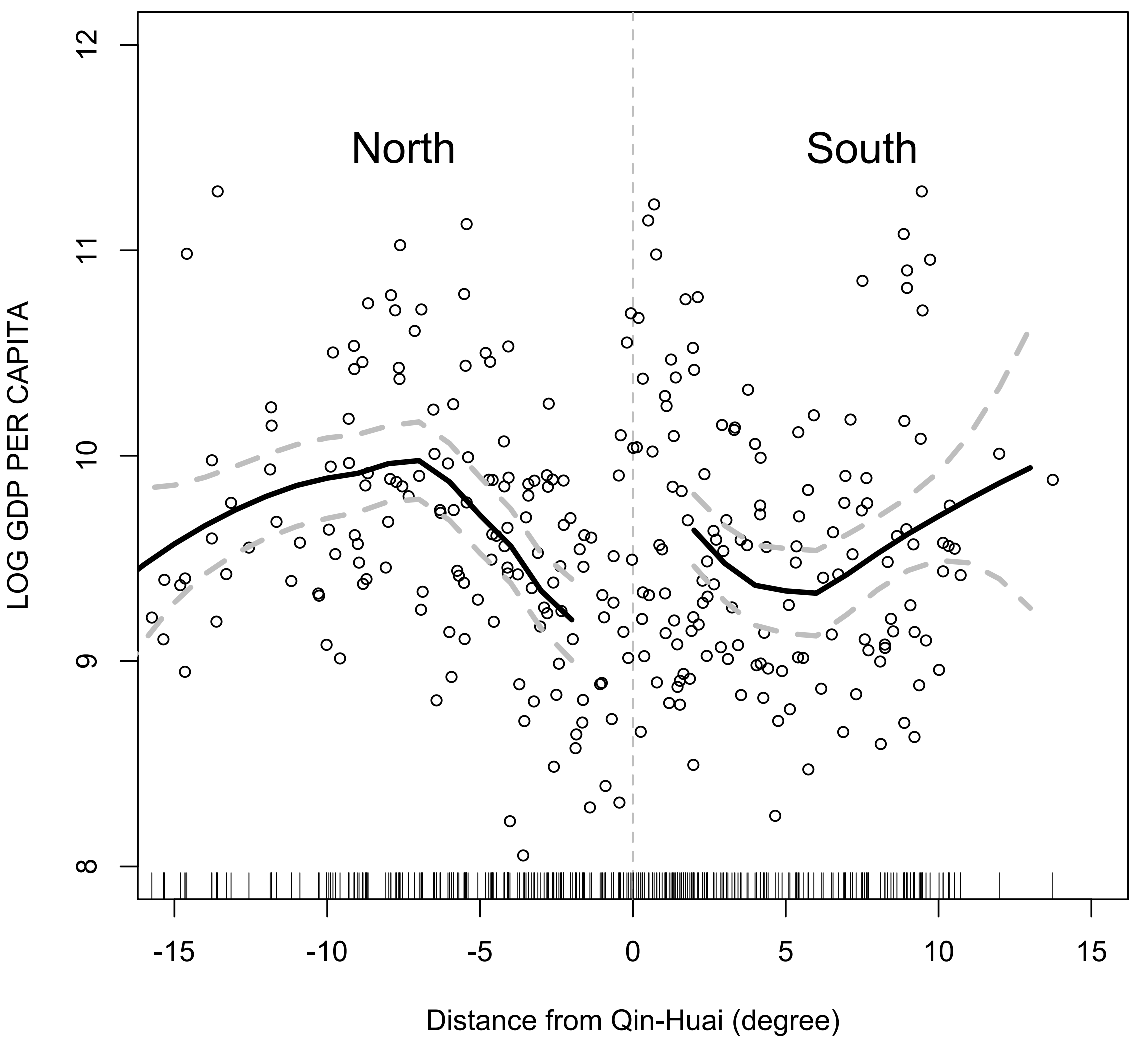

Figure 3: Log per capita GDP by Latitude (Centered at the Qin-Huai Line)

Notes: The figure plots LOG PER CAPITA GDP over LATITUDE, with LATITUDE centered at 32° N latitude. The lines are from local linear regression smoother fits to the prefectures. The local linear regression smoothers are fit on either side of the cut point, demarcated by the vertical line. Positive distances represent south, negative distances present north. The rug indicates the actual distribution of prefectures in the sample. The grey dotted line represents the 95% confidence interval. The jump of LOG PER CAPITA GDP at the cut point is estimated to be 0.319 (s.e. clustered by latitude=0.118) with the "Imbens-Kalyanaraman optimal" bandwidth of 3.68° and a rectangle kernel. Table A2b in the web appendix provides the full results.

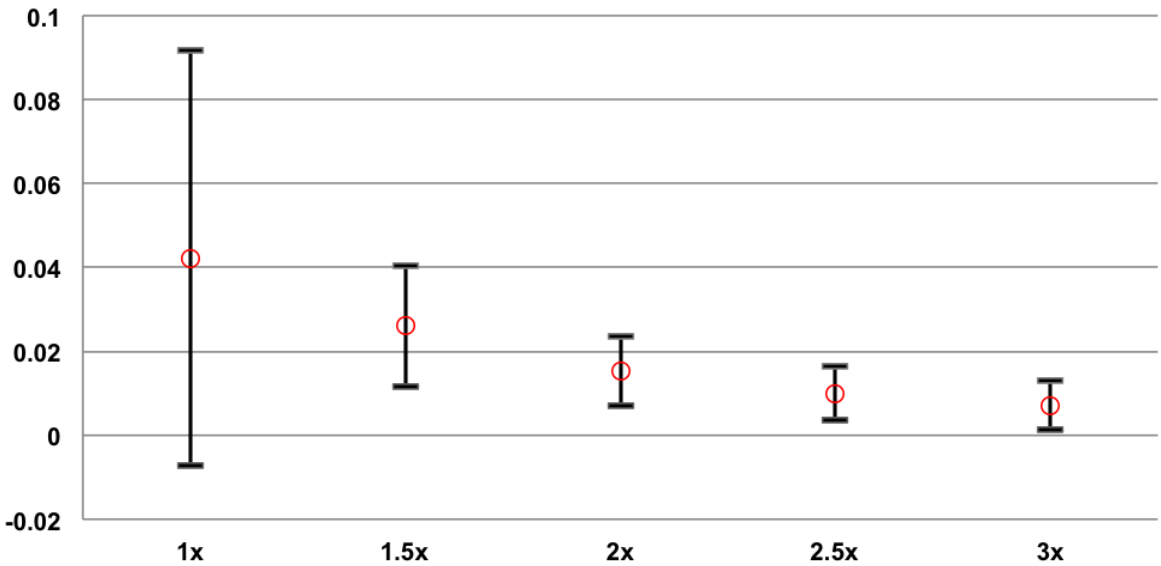

Figure 4: 2SLS Estimates by Bandwidth

Notes: The figure plots the 2SLS estimate of the coefficient of RICE on LOG PER CAPITA GDP by different bandwidths (1×, 1.5×, 2×, 2.5×, 3× the optimal bandwidth). The circles indicate the point estimates, and the bars 95% confidence intervals.