Large-Scale Psychological Differences Within China Explained by Rice Versus Wheat Agriculture

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Large-Scale Psychological Differences Within China Explained by Rice Versus Wheat Agriculture

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Cross-cultural psychologists have mostly contrasted East Asia with the West. However, this study shows that there are major psychological differences within China. We propose that a history of farming rice makes cultures more interdependent, whereas farming wheat makes cultures more independent, and these agricultural legacies continue to affect people in the modern world. We tested 1162 Han Chinese participants in six sites and found that rice-growing southern China is more interdependent and holistic-thinking than the wheat-growing north. To control for confounds like climate, we tested people from neighboring counties along the rice-wheat border and found differences that were just as large. We also find that modernization and pathogen prevalence theories do not fit the data.

Over the past 20 years, psychologists have cataloged a long list of differences between East and West (1–3). Western culture is more individualistic and analytic-thinking, whereas East Asian culture is more interdependent and holistic-thinking. Analytic thought uses abstract categories and formal reasoning, such as logical laws of noncontradiction—if A is true, then "not A" is false. Holistic thought is more intuitive and sometimes even embraces contradiction—both A and "not A" can be true.

Even though psychology has cataloged a long list of East-West differences, it still lacks an accepted explanation of what causes these differences. Building on subsistence style theory (1, 4), we offer the rice theory of culture and compare it with the modernization hypothesis (5) and the more recent pathogen prevalence theory (6).

The modernization hypothesis argues that, as societies become wealthier, more educated, and capitalistic, they become more individualistic and analytical. World Values Surveys (7) and studies on indigenous Mayans' transition to a market economy (5) have given some support to the modernization hypothesis. But this theory has difficulty explaining why Japan, Korea, and Hong Kong are persistently collectivistic despite per-capita gross domestic products (GDPs) higher than that of the European Union.

The pathogen prevalence theory argues that a high prevalence of communicable diseases in some countries made it more dangerous to deal with strangers, making those cultures more insular and collectivistic (6). Studies have found that historical pathogen prevalence correlates with collectivism and lower openness to experience (6). However, pathogens are strongly correlated with heat (8). Because rice grows in hot areas, pathogens may be confounded with rice—a possibility that prior research did not control for.

The Rice Theory

The rice theory is an extension of subsistence style theory, which argues that some forms of subsistence (such as farming) require more functional interdependence than other forms (such as herding). At the same time, ecology narrows the types of subsistence that are possible. For example, paddy rice requires a significant amount of water. Over time, societies that have to cooperate intensely become more interdependent, whereas societies that do not have to depend on each other as much become more individualistic.

In the past, most subsistence research has compared herders and farmers, arguing that the independence and mobility of herding make herding cultures individualistic and that the stability and high labor demands of farming make farming cultures collectivistic (1). We argue that subsistence theory is incomplete because it lumps all farming together. Two of the most common subsistence crops—rice and wheat—are very different, and we argue that they lead to different cultures.

The two biggest differences between farming rice and wheat are irrigation and labor. Because
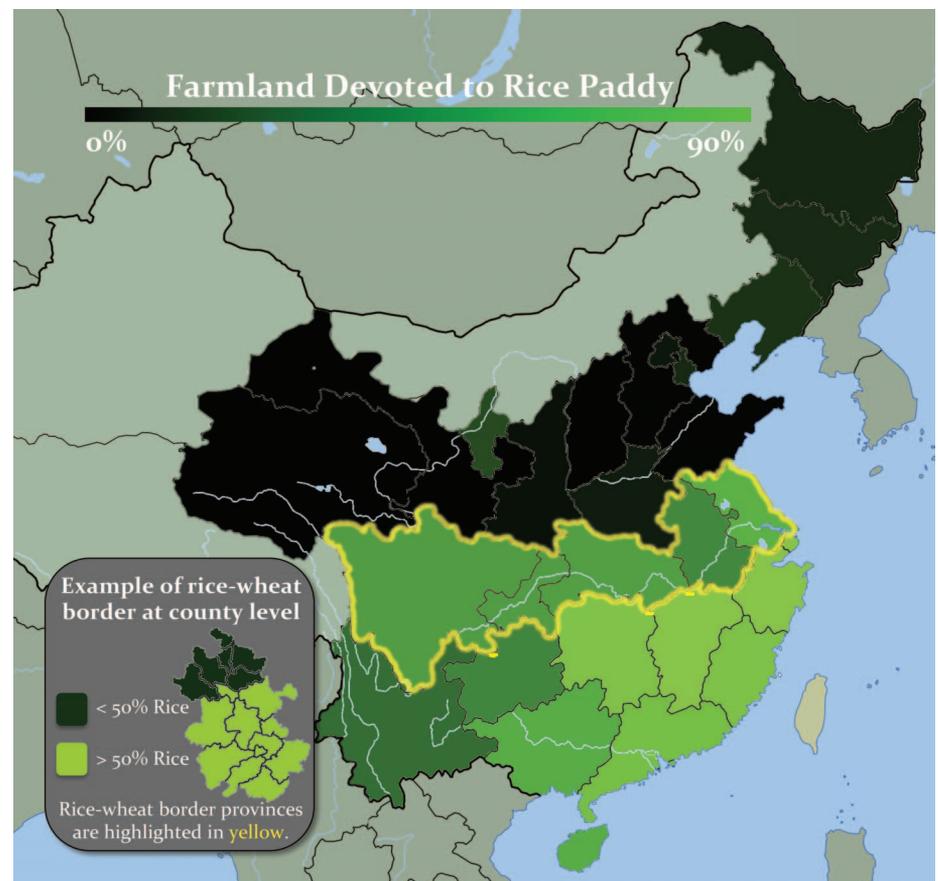
Fig. 1. Percent of cultivated land devoted to rice paddies in 1996. Three major herding provinces are not shaded: Tibet, Xinjiang, and Inner Mongolia. Along the rice-wheat border (highlighted), people from the rice counties thought more holistically than their neighbors in wheat counties.

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rice paddies need standing water, people in rice regions build elaborate irrigation systems that require farmers to cooperate. In irrigation networks, one family's water use can affect their neighbors, so rice farmers have to coordinate their water use. Irrigation networks also require many hours each year to build, dredge, and drain—a burden that often falls on villages, not isolated individuals.

Paddy rice also requires an extraordinary amount of work. Agricultural anthropologists visiting premodern China observed the number of hours farmers worked and found that growing paddy rice required at least twice the number of hours as wheat (9). The difference in man-hours was not a difference only noticeable to scientists. Medieval Chinese people grew both wheat and rice, and they were aware of the huge labor difference between the two. A Chinese farming guide

in the 1600s advised people, "If one is short of labor power, it is best to grow wheat" [quoted in (10)]. A Chinese anthropologist in the 1930s concluded that a husband and wife would not be able to farm a large enough plot of rice to support the family if they relied on only their own labor (11). Strict self-reliance might have meant starvation.

To deal with the massive labor requirements, farmers in rice villages from India to Malaysia and Japan form cooperative labor exchanges (12). Farmers also coordinate their planting dates so that different families harvest at different times, allowing them to help in each others' fields (12). These labor exchanges are most common during transplanting and harvesting, which need to be done in a short window of time, creating an urgent need for labor. In economic terms, paddy rice makes cooperation more valuable. This en-

courages rice farmers to cooperate intensely, form tight relationships based on reciprocity, and avoid behaviors that create conflict.

In comparison, wheat is easier to grow. Wheat does not need to be irrigated, so wheat farmers can rely on rainfall, which they do not coordinate with their neighbors. Planting and harvesting wheat certainly takes work, but only half as much as rice (9). The lighter burden means farmers can look after their own plots without relying as much on their neighbors.

One point of clarification about the rice theory is that it applies to rice regions, not just the people farming rice. It is a safe bet that none of our thousand participants have actually farmed rice or wheat for a living. Instead, the theory is that cultures that farm rice and wheat over thousands of years pass on rice or wheat cultures,

Table 1. Holistic thought hierarchical linear models for rice (28 provinces, 1019 participants), GDP per capita (28 provinces, 1019 participants), and pathogens (21 provinces, 725 participants). See supplementary materials for detailed information on site effects and regressions with GDP, rice, and pathogens in a single model. Gender is coded as 0 = male and 1 = female.

	B	SE	z	P	B	SE	z	P	B	SE	z	P
Gender	0.20	0.06	3.55	<0.001	0.20	0.06	3.53	<0.001	0.13	0.07	1.97	0.05
Site$_{Fujian}$	−0.34	0.11	−3.21	0.001	−0.33	0.11	−3.07	0.002	−0.36	0.12	−3.09	0.002
Rice	0.56	0.21	2.72	0.007								
Per-capita GDP					0.52[1]	0.23[1]	2.24[1]	0.03[1]				
Pathogens									−0.22[1]	0.10[1]	−2.08[1]	0.04[1]

[1]Predictor correlates in the opposite direction from what theory predicts.

Table 2. Implicit individualism and loyalty/nepotism hierarchical linear models for rice, GDP per capita, and pathogens. Implicit individualism N equals 28 provinces, 515 participants for rice and GDP. N equals 21 provinces and 452 participants for pathogens. Loyalty/nepotism N equals 27 provinces, 166 participants for rice and GDP. N equals 21 provinces and 146 participants for pathogens.

	B	SE	t	P	B	SE	t	P	B	SE	t	P
					Implicit individualism							
Gender	−0.06	0.02	−2.51	0.01	−0.05	0.02	−2.34	0.02	−0.05	0.02	−2.04	0.04
Site$_{BeijingW2011}$	−0.27	0.05	−5.18	<0.001	−0.25	0.06	−4.40	<0.001	−0.18	0.05	−3.44	0.001
Rice	−0.20	0.08	−2.57	0.016								
Per-capita GDP					0.01	0.15	0.07	0.95				
Pathogens									0.01[1]	0.04[1]	0.33[1]	0.74[1]
					Loyalty/Nepotism							
Site$_{Sichuan}$	2.04	0.83	2.47	0.01	1.63	0.87	1.88	0.06	1.91	0.85	2.25	0.03
Rice	2.45	1.16	2.12	0.04								
Per-capita GDP					1.66[1]	1.69[1]	0.98[1]	0.34[1]				
Pathogens									−0.13	0.62	−0.21	0.84

[1]Predictor correlates in the opposite direction from what theory predicts.

Table 3. Divorce and invention regression models for rice, GDP per capita, and pathogens. Divorces are calculated as divorces per marriage, with 27 provinces for rice and per-capita GDP models and 21 provinces for pathogens. Inventions are the log number of successful patents per capita. Inventions N equals 27 provinces for rice and GDP; N equals 21 for pathogens.

	B	SE	β	t	P	B	SE	β	t	P	B	SE	β	t	P
						Divorces									
Per-capita GDP	0.10	0.04	0.48	2.71	0.01	0.13	0.03	0.61	3.89	0.001	0.11	0.05	0.52	2.04	0.06
Rice						−0.11	0.04	−0.49	−3.11	0.005					
Pathogens											−0.01	0.03	−0.07	−0.26	0.80
						Inventions									
Per-capita GDP	2.22	0.41	0.73	5.37	<0.001	2.55	0.37	0.84	6.98	<0.001	1.78	0.59	0.60	3.00	0.008
Rice						−1.27	0.39	−0.39	−3.28	0.003					
Pathogens											−0.34	0.31	−0.22	−1.10	0.29

even after most people put down their plows. Simply put, you do not need to farm rice yourself to inherit rice culture.

We propose that the rice theory can partly explain East-West differences. Prior subsistence theory cannot fully explain East-West differences because it focuses on herding versus farming (*1*), which is not the main East-West difference. Several Western regions herd, such as parts of Scotland and Switzerland, but the bulk of Europe historically farmed wheat (and similarly grown crops, such as barley). Instead, rice-wheat is the main East-West difference, and psychologists have not studied it.

The easiest way to test whether rice and wheat lead to different cultures is to show that rice areas (East Asia) are interdependent and that wheat areas (the West) are independent. But that logic is obviously flawed. We cannot just compare East and West because they differ on many factors besides rice and wheat—religion, politics, and technology, to name a few. A more convincing test case would be a country that has a shared history, government, language, and religion, but farms rice in some areas and wheat in other areas.

China as a Natural Test Case

Han China is a fitting natural test case because it has traditionally grown both rice and wheat but is more ethnically and politically unified than, say, Europe or sub-Saharan Africa. China is over 90% Han Chinese, and the same dynasties have ruled over the wheat and rice cores for most of the past few thousands of years, which controls for some of the major variables that confound East-West comparisons.

Within China, the Yangtze River splits the wheat-growing north from the rice-growing south (Fig. 1). For generations, northern China has grown wheat, and southern China has grown rice. Of course, two regions can never be 100% equivalent. There are differences such as climate and spoken dialect between north and south. To rule out these smaller differences, we report additional analyses that compare people from neighboring counties along the rice-wheat border.

Three Predictions

The three theories make different predictions about which parts of China should be the most interdependent. First, the modernization hypothesis predicts that the least-developed provinces should be the most interdependent. Development has been uneven in China partly because in the late 1970s Deng Xiaoping made several areas along the southeast coast "special economic zones" open to foreign trade. This policy has given southeastern provinces like Guangdong a GDP per capita about 3.5 times that of interior provinces like Guizhou (*13*). That is roughly the ratio difference between the United States and Kazakhstan. Thus, modernization would predict the highest collectivism in China's least-developed interior provinces.

Second, pathogen prevalence theory predicts a gradual rise in interdependence from north to south because pathogens rise gradually along with temperatures (*8*). Among Chinese provinces, overall pathogen rates and latitude are correlated: $r(20) = -0.49$, $P = 0.02$ (*14*). Furthermore, pathogen theory would predict the highest interdependence in the southwest, which has the highest rates of infectious disease death.

Third, the rice theory predicts the highest interdependence in the south and east. Unlike pathogens, rice is not the highest in the southernmost provinces. Instead, rice is concentrated in the east around Shanghai, which has flat floodplains ideal for growing rice. The rice theory also predicts a sharp divide along the rice-wheat border, which is different from the gradual rise of pathogens with climate.

To measure the prevalence of rice farming, we used statistical yearbook data on the percentage of cultivated land in each province devoted to rice paddies (*13*). Because some rice is grown with less labor on dry land (without paddies), we used statistics on rice paddies, rather than rice output. Because we wanted to assess the crop that different regions farmed traditionally, rather than figures affected by recent advances in irrigation and mechanization, we used rice statistics from 1996, the earliest available on the Bureau of Statistics Web site.

To test the modernization hypothesis, we collected GDP per capita for each province from the same year. To measure precontemporary disease prevalence, we used the earliest study we could find with disease rates in different provinces, from 1976 (*15*). Because the 1976 study did not cover 10 provinces, we also collected recent statistics (*13*). This increased the sample by four provinces. Both sources gave similar pictures: higher disease in the south and the highest in the southwest.

Samples

We tested 1162 Han Chinese students from six sites: Beijing (north), Fujian (southeast), Guangdong (south), Yunnan (southwest), Sichuan (west central), and Liaoning (northeast). We used three measures: a measure of cultural thought, implicit individualism, and loyalty/nepotism (described below). We chose these tasks because they are not self-report scales, avoiding the documented problems with use of self-report scales to measure cultural differences (*16*).

Results from these different sites show that rice-wheat differences held regardless of testing site (*14*). For all tasks, we analyzed only ethnic Han Chinese and excluded Han participants from the provinces of Tibet, Inner Mongolia, and Xinjiang. These areas are historically herding areas and have different ethnicities, cultures, languages, and religions that would confound our comparisons of rice and wheat.

We tested the hypotheses with multilevel models because participants (level 1) were nested within provinces (level 2). We report correlations as an effect size at the province level that can be compared across variables. We calculated this by comparing the province-level variance of the
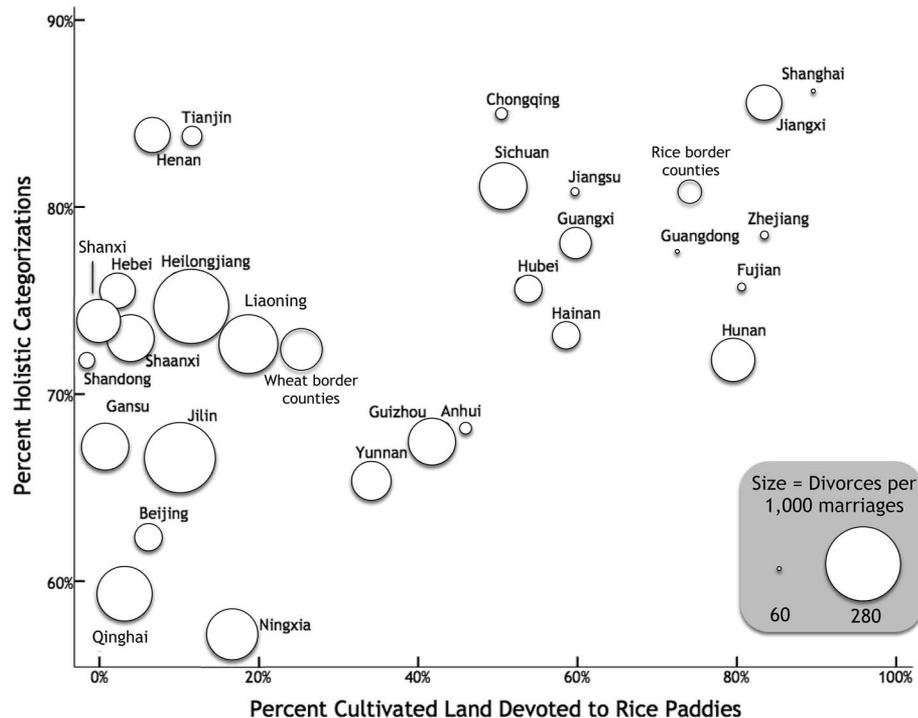
Fig. 2. Cultural thought style by percentage of cultivated area devoted to rice paddies. Each circle represents a province. Circle size represents divorce and controls for effect of GDP. To illustrate cultural differences along the rice-wheat border, circles represent the rice and wheat border counties.

models with and without the key predictor (Tables 1 to 3 report regression output).

Our main dependent variable was a common measure of cultural thought, the triad task (*17*). The triad task shows participants lists of three items, such as train, bus, and tracks. Participants decide which two items should be paired together. Two of the items can be paired because they belong to the same abstract category (train and bus belong to the category vehicles), and two because they share a functional relationship (trains run on tracks). People from Western and individualistic cultures choose more abstract (analytic) pairings, whereas East Asians and people from other collectivistic cultures choose more relational (holistic) pairings (*1, 17*). We report scores as a percentage of holistic choices, where 100% is completely holistic and 0% is completely analytic.

We first tested the modernization hypothesis by testing whether people from provinces with lower GDP per capita thought more holistically. People from richer provinces actually thought more holistically: $\gamma(25) = 0.52$, $P = 0.03$, $r = 0.46$. (γ represents province-level HLM regression coefficients.)

We then tested the pathogen prevalence theory by testing whether provinces with higher rates of disease thought more holistically. Provinces with higher disease rates actually thought less holistically: $\gamma(18) = -0.22$, $P = 0.04$, $r = -0.44$.

The large-scale disease study from 1976 included statistics for 31 counties across China (*15*), which let us test the pathogen theory more precisely. Thus, we tested whether the 198 people in our sample who came from these 31 counties had different thought styles based on the historical disease prevalence in their county. Even with this finer precision, pathogen prevalence predicted thought style marginally in the wrong direction: $\gamma(28) = -0.43$, $P = 0.08$, $r = -0.33$.

The rice theory was the only model that fit the data (Fig. 2). People from provinces with a higher percentage of farmland devoted to rice paddies thought more holistically: $\gamma(25) = 0.56$, $P = 0.007$, $r = 0.51$. [Controlling for GDP per capita made little difference (table S1).]

Northern and southern China also differ in several factors other than rice, such as climate, dialect, and contact with herding cultures. Therefore, we analyzed differences among neighboring counties along in the five central provinces along the rice-wheat border (Sichuan, Chongqing, Hubei, Anhui, and Jiangsu). Differences between neighboring counties are less likely to be due to climate or other third variables.

We gathered the rice cultivation statistics for each county in these provinces and split counties into rice and wheat counties. We defined rice counties as more than 50% of farmland devoted to rice paddies. Figure 1 depicts an example of the county split in the province of Anhui. The rice-wheat difference between neighboring counties can be stark. For example, in Anhui, Bozhou county farms only 2% rice, whereas neighboring

Huainan county farms 67%. We tested for differences in cultural thought style, which had the largest sample, including 224 participants from the rice-wheat border.

People from the rice side of the border thought more holistically than people from the wheat side of the border: $B(221) = 0.54$, $P < 0.001$ (table S5). To compare the border effect size with the effect size for rice and wheat in all of China, we compared effect of a categorical rice-wheat variable. The effect sizes were similar (rice-wheat border, $B = 0.53$; all China, $B = 0.43$). (For group comparisons, wheat provinces are defined throughout as <50% farmland devoted to rice paddies; rice provinces as >50%.)

To test whether the findings generalize beyond thought style, we tested subsamples on two measures previously used for East-West cultural differences. The first was the sociogram task ($n = 515$), which has participants draw a diagram of their social network, with circles to represent the self and friends (*18*). Researchers measure how large participants draw the self versus how large they draw their friends to get an implicit measure of individualism (or self-inflation). A prior study found that Americans draw themselves about 6 mm bigger than they draw others, Europeans draw themselves 3.5 mm bigger, and Japanese draw themselves slightly smaller (*18*).

People from rice provinces were more likely than people from wheat provinces to draw themselves smaller than they drew their friends: $\gamma(24) = -0.20$, $P = 0.03$, $r = -0.17$ (fig. S2). On average, people from wheat provinces self-inflated 1.5 mm (closer to Europeans), and people from rice provinces self-inflated -0.03 mm (similar to Japanese).

Pathogen prevalence did not predict self-inflation on the sociogram task: $\gamma(17) = 0.003$, $P = 0.95$, $r = 0$. GDP per capita also failed to predict self-inflation: $\gamma(24) = 0.04$, $P = 0.81$, $r = 0$.

The second measure was the loyalty and nepotism task, which measures whether people draw a sharp distinction between how they treat friends versus strangers ($n = 166$). One defining feature of collectivistic cultures is that they draw a sharp distinction between friends and strangers (*3*). A previous study measured this by having people imagine going into a business deal with (i) an honest friend, (ii) a dishonest friend, (iii) an honest stranger, and (iv) a dishonest stranger (*19*). In the stories, the friend or stranger's lies cause the participant to lose money in a business deal, and the honesty causes the participant to make more money. In each case, the participants have a chance to use their own money to reward or punish the other person.

The original study found that Singaporeans rewarded their friends much more than they punished them, which could be seen positively as loyalty or negatively as nepotism (*19*). Americans were much more likely than Singaporeans to punish their friends for bad behavior. We pre-

Table 4. Instrumental variable regressions. Instrumental variable regressions help test whether reverse causality is a problem in the data set—whether regions that were already more collectivistic chose to grow rice. In the topmost regression, "rice suitability" is a *z* score of the environmental suitability of each province for growing wetland rice based on the United Nations Food and Agriculture Organization's Global Agro-ecological Zones database (*27*). In the five other regressions, "rice suitability" is the predicted rice from the topmost regression with rice suitability. Dash entries indicate not applicable.

	B	SE	β	*t/z*	*P*
Actual rice farming					
Rice suitability	0.27	0.03	0.85	8.31	<0.001
28 provinces					
Holistic thought					
Gender	0.20	0.06	–	3.56	<0.001
Site$_{Fujian}$	−0.34	0.11	–	−3.16	0.002
Rice suitability	0.66	0.25	–	2.66	0.008
28 provinces, 1019 participants					
Implicit individualism					
Gender	−0.05	0.02	–	−2.35	0.02
Site$_{BeijingW2011}$	−0.24	0.05	–	−4.87	<0.001
Rice suitability	−0.24	0.10	–	−2.47	0.02
28 provinces, 510 participants					
Loyalty/nepotism					
Site$_{Sichuan}$	1.64	0.80	–	2.05	0.04
Rice suitability	3.73	1.40	–	2.67	0.009
27 provinces, 176 participants					
Divorces					
Per-capita GDP	0.11	0.03	0.51	3.65	0.001
Rice suitability	−0.15	0.04	−0.56	−4.04	<0.001
27 provinces					
Inventions					
Per-capita GDP	2.30	0.34	0.76	6.68	<0.001
Rice suitability	−1.50	0.43	−0.40	−3.50	<0.002
27 provinces					

dicted that people from rice areas would be less likely to punish their friends than people from wheat areas.

We computed loyalty/nepotism as the amount they rewarded their friend minus the amount they punished their friend. People from rice provinces were more likely to show loyalty/nepotism: $\gamma(25) = 2.45$, $P = 0.04$, $r = 0.49$. In their treatment of strangers, people from rice and wheat provinces did not differ: $\gamma(24) = -0.09$, $P = 0.90$, $r = 0$.

Pathogen prevalence was not related to loyalty/nepotism: $\gamma(19) = -0.13$, $P = 0.84$, $r = -0.08$. GDP per capita did not predict loyalty/nepotism: $\gamma(25) = 1.66$, $P = 0.36$, $r = 0.33$.

In short, the results consistently showed that participants from rice provinces are more holistic-thinking, interdependent, and loyal/nepotistic than participants from the wheat provinces. However, one weakness of these studies is that the participants were all college students. To test whether the cultural differences extend beyond college students, we gathered provincial statistics on variables that have been linked to collectivism and analytic thought: divorce rates and patents for new inventions.

A prior study showed that individualistic countries have higher divorce rates, even controlling for gross national product per capita (20). Rice culture's emphasis on avoiding conflict and preserving relationships may make people from rice cultures less willing to get divorced. We collected divorce statistics from the same statistical yearbook as the farming statistics, 1996. We also collected statistics from the 2000 and the 2010 yearbooks to track the differences over the past 15 years.

In China, modernization did predict divorce: wealthier provinces had more divorce: $B(26) = 0.10$, $P = 0.01$, $\beta = 0.48$. Adding rice to the model explained even more variation in divorce rates, with rice provinces having lower divorce rates: $B(25) = -0.11$, $P = 0.005$, $\beta = -0.49$. Pathogen prevalence did not predict divorce: $B(20) = -0.01$, $P = 0.80$, $\beta = -0.07$ (controlling for GDP). In 1996, wheat provinces had a 50% higher divorce rate than rice provinces. Although divorce rates have almost doubled in the past 15 years, the raw divorce rate gap between the wheat and rice provinces remained the same in the 2000 and 2010 statistics.

We also analyzed the number of successful patents for new inventions in each province because research has shown that analytic thinkers are better at measures of creativity and thinking of novel uses for ordinary objects (21). Within the United States, immigrants from individualistic cultures hold more patents for inventions (22).

We controlled for GDP per capita because wealthier provinces had more patents: $B(26) = 2.22$, $P < 0.001$, $\beta = 0.73$. Rice provinces had fewer successful patents for new inventions than wheat provinces: $B(25) = -1.27$, $P = 0.003$, $\beta = -0.39$. Pathogen prevalence did not predict patents: $B(19) = -0.34$, $P = 0.29$, $\beta = -0.22$. Wheat provinces had 30% more patents for inven-

tions than rice provinces. This difference persisted through the 2000 statistics but not the 2010 statistics.

This study shows that China's wheat and rice regions have different cultures. China's rice regions have several markers of East Asian culture: more holistic thought, more interdependent self-construals, and lower divorce rates. The wheat-growing north looked more culturally similar to the West, with more analytic thought, individualism, and divorce. Furthermore, Table 4 presents an instrumental variable regression showing that climatic suitability for rice significantly predicts all of the cultural variables in this study, which suggests that reverse causality is unlikely.

How large are these differences compared with East-West differences? We compared results on our main task (cultural thought style) in our China sample to a prior U.S. sample. An East-West categorical variable had an effect of $B = 0.78$. In the China data, a categorical rice-wheat variable had an effect of $B = 0.38$ (table S2). This suggests that rice versus wheat can explain a portion of the variance in thought style between East and West but not all of it. It should also be noted that psychologists have found holistic thought in parts of the world beyond East Asia, which suggests holistic thought is not just an East-West difference (23).

Modernization predicted divorce and patents, but why did it fail to predict the other differences? In China, modernization seems to have changed customs such as divorce, but perhaps the parts of culture and thought style we measured are more resistant to change. Or perhaps modernization simply takes more generations to change cultural interdependence and thought style. However, most of our participants were born after China's reform and opening, which started in 1978. Furthermore, Japan, South Korea, and Hong Kong modernized much earlier than China, but they still score less individualistic on international studies of culture than their wealth would predict (fig. S2).

The rice theory can explain wealthy East Asia's strangely persistent interdependence. China has a rice-wheat split, but Japan and South Korea are complete rice cultures. Most of China's wheat provinces devote less than 20% of farmland to rice paddies. None of Japan's 9 regions or South Korea's 16 regions has that little rice (except for two outlying islands). Japan and Korea's rice legacies could explain why they are still much less individualistic than similarly wealthy countries.

This study focuses on East Asia, but the rice theory also makes predictions about other parts of the world. For example, India has a large rice-wheat split. Indonesia and parts of West Africa have also traditionally farmed rice. If the rice theory is correct, we should find similar cultural differences there.

There are still unresolved questions with the rice theory. For example, studies can test whether irrigation is central to the effect of rice by comparing paddy rice with dryland rice cultures,

which grow rice without irrigation. Studies can also explore how rice differences persist in the modern world, whether through values, institutions, or other mechanisms.

There is also the question of how long rice culture will persist after the majority of people stop farming rice. There is evidence that U.S. regions settled by Scottish and Irish herders have higher rates of violence, even though most locals stopped herding long ago (24). This is one example of how subsistence style can shape culture long after people have stopped relying on that subsistence style. In the case of China, only time will tell.

Psychologists, economists, and anthropologists have studied the effects of subsistence style and irrigation (1, 4, 25, 26). This study extends that work by using psychological measures to test differences resulting from rice and wheat agriculture. The rice theory provides a theoretical framework that might explain why East Asia is so much less individualistic than it "should be" based on its wealth. Finally, the rice theory can explain the large cultural differences within China, advancing a more nuanced picture of East Asian cultural diversity.

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REPORTS

Fermi Surface and Pseudogap Evolution in a Cuprate Superconductor

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The unclear relationship between cuprate superconductivity and the pseudogap state remains an impediment to understanding the high transition temperature (T_c) superconducting mechanism. Here, we used magnetic field–dependent scanning tunneling microscopy to provide phase-sensitive proof that d-wave superconductivity coexists with the pseudogap on the antinodal Fermi surface of an overdoped cuprate. Furthermore, by tracking the hole-doping (p) dependence of the quasi-particle interference pattern within a single bismuth-based cuprate family, we observed a Fermi surface reconstruction slightly below optimal doping, indicating a zero-field quantum phase transition in notable proximity to the maximum superconducting T_c. Surprisingly, this major reorganization of the system's underlying electronic structure has no effect on the smoothly evolving pseudogap.
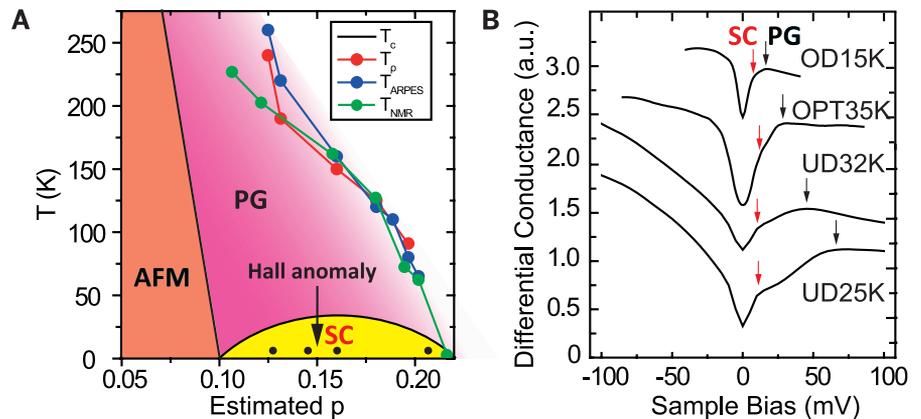
Superconductivity is one of several phenomena, including the pseudogap, that arises from interactions of electrons near the Fermi surface (FS) in hole-doped cuprates. The FS topology is therefore crucial to understanding these phenomena and their relationships. High-field quantum oscillation (QO) measurements (*1–3*) revealed an unexpectedly small FS in underdoped $YBa_2Cu_3O_{6.5}$ (YBCO), in contrast to the conventional, large FS of overdoped cuprates like $Tl_2Ba_2CuO_{6+x}$ (*4*). Further high-field investigations led to the discovery of a quantum phase transition (QPT) at the low doping edge of this small FS regime, perhaps associated with a metal-insulator transition (*5*) or the formation of density-wave order (*6*). However, the large-to-small FS transition presumed to occur at higher doping has thus far not been observed by QO within a single hole-doped material system. Furthermore, it is unclear whether the small FS is merely revealed by QO or possibly created by their necessarily high magnetic fields.

A zero-field alternative to QO, angle-resolved photoemission spectroscopy (ARPES), has a long history of mapping the FS in $Bi_2Sr_2CaCu_2O_{8+x}$ (Bi2212) (*2*, *7–11*). Here, the onset of the pseudogap (PG) is defined by the opening of an antinodal gap and the reduction of the large FS to a "Fermi arc," which may actually be one side of a Fermi pocket, consistent with QO results (*10*). The PG onset may be associated with a QPT just above optimal doping at $p = 0.19$ (*11*). A second QPT to another competing phase is suggested to occur (*11*) at lower doping ($p = 0.076$), similar perhaps to that found by QO (*5*, *6*). However, if the transition near optimal doping is a FS reconstruction to pockets, as suggested in (*10*), why are sharp antinodal quasiparticles seen below this doping, all the way down to $p = 0.08$ (*7*, *9*, *11*)? Further, if the antinodal FS persists down to $p = 0.08$, what impact does the QPT associated with the onset of the PG at $p = 0.19$ have on the FS?

To address these outstanding questions, we used scanning tunneling microscopy (STM) to study $(Bi,Pb)_2(Sr,La)_2CuO_{6+\delta}$ (Bi2201). In this hole-doped cuprate, the absence of bilayer splitting and the suppression of the supermodu-

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Fig. 1. Phase diagram and spectra. (A) Schematic temperature-doping phase diagram of Bi2201, showing antiferromagnetic insulator (AFM), superconductor (SC), and PG phases. Four black points represent the sample batches of this study, namely underdoped UD25K and UD32K, optimal OPT35K, and overdoped OD15K. The PG transition line T^* is plotted as measured by ARPES (*12*), resistivity (*12*) and nuclear magnetic resonance (*13*). Anomaly in the Hall coefficient (*28*) is marked by a black arrow. **(B)** The spatially averaged differential conductance $g(E)$ for each sample. The PG edge is marked with black arrows, whereas the low-energy kink in each spectrum, considered to be related to the superconducting gap (*14*, *15*), is marked with red arrows. a.u., arbitrary units.