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Does Rice Farming Shape Individualism and Innovation?

A Response to Talhelm et al. (2014)

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ABSTRACT

Talhelm et al. (2014) provided an original rice theory to explain large psychological differences across countries and even within countries and their impact on innovation. However, their findings are subject to the problems of sample bias, measurement error, and model misspecification. After correcting these problems, most findings in the original paper no longer hold. The authors of this paper collected data on collectivism from other sources and linked them with rice areas but failed to find any relationship as predicted by the rice theory. The role of rice farming in shaping cultural psychology and innovations seems to be much more muted.

Keywords: rice theory, individualism, innovation

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1. INTRODUCTION

Large psychological differences in individualism, analytic thinking, and loyalty/nepotism across countries and even within countries have been noted in the real world and literature for a long time (O'Neill 1973; Kim 1994; Triandis 1995; Vandello and Cohen 1999). Talhelm et al. (2014) offered an original rice theory to explain such a difference. Their story is intuitively appealing. Rice faming is both labor and water intensive. During the peak seasons, farmers adjust their schedules of transplanting and harvest so that they can exchange labor to ease the problem of seasonal labor shortage. Paddy rice requires standing water. Therefore, people in rice regions must collaborate to build elaborate irrigation systems, coordinate water use, and share the cost of construction and maintenance. All these activities involve comprehensive collaboration and coordination, encouraging farmers to form tight reciprocal relationship and avoid conflict. The rice theory hypothesizes that after thousands of years of farming practice, people living in rice-cultivating regions develop a higher degree of interdependence and collectivism than those living in wheat areas.

However, it is difficult to test the theory across countries because of inherent differences in many factors, such as language, religion, politics, and climate. The authors chose to test it within China by taking advantage of the homogeneity among the Han population. They surveyed more than 1,000 Han Chinese college students and found that rice-growing southern China exhibits lower individualism and more holistic thinking than the wheat-growing north. By using secondary data at the provincial level, they also showed that people in rice-cultivating areas of China are subject to a lower divorce rate and hold fewer patents for inventions compared to wheat-cultivating areas. Because rice culture emphasizes avoiding conflict and valuing relationships, the lower divorce rate in rice-cultivating provinces provides strong evidence in support of the rice theory. As individualism and analytical thinking are normally tied to creativity, the smaller number of successful invention patents in rice areas in comparison to wheat areas offers additional support to the rice theory. Drawing on the findings of the paper, Henrich (2014) speculated that wheat farming in Europe may have contributed to the industrial revolution. The rice theory is so appealing and profound that Science highlighted the article on the cover page and many media covered the story.

The theory is truly original. It sheds new light on understanding the interplay among environment, culture, psychology, and innovations. Given the originality and potential far-reaching impact of Talhelm et al. (2014), it is critical to replicate and validate the findings of the paper. This is the main objective of this paper. We found that Talhelm et al.'s analyses were subject to sample bias, measurement errors, and model misspecifications. After correcting these problems, most findings in the original paper no longer hold. We further collected data on collectivism from other sources and linked them with rice areas but failed to find any relationship as predicted by the rice theory. The role of rice farming in shaping cultural psychology and innovations seems to be much more muted.

2. SAMPLE BIAS

Talhelm et al. conducted three experiments to measure cultural thought, implicit individualism, and loyalty/nepotism in six sites. Ideally, the sampling size in each province should be proportional to the total population in the province. However, as shown in Table 2.1, the sample distribution is highly uneven. In the experiment on holistic thought, there are a total of 1,019 observations scattered across 28 provinces. Among the sample, Guangdong province commands the largest number of observations (193, or 18.94 percent of the total), more than double its population share. Fujian province accounts for 14.62 percent of the total sample size, compared to its 2.88 percent of population share. In comparison, only 2 individuals were surveyed in Beijing, constituting merely 0.20 percent of the sample, much lower than its population share of 1.53 percent.

Table 2.1 Sample Distribution of Talhelm et al. (2014)

Province	Holistic thought		Implicit individualism		Loyalty/nepotism		Population share (%)
	Sample Number	Share (%)	Sample Number	Share (%)	Sample Number	Share (%)	
Qinghai	3	0.29	1	0.19	—	—	0.44
Ningxia	8	0.79	5	0.97	1	0.60	0.49
Hainan	12	1.18	7	1.36	5	3.01	0.68
Tianjin	8	0.79	5	0.97	2	1.20	1.01
Beijing	2	0.20	6	1.17	2	1.20	1.53
Shanghai	10	0.98	2	0.39	1	0.60	1.79
Gansu	28	2.75	21	4.08	2	1.20	1.99
Jilin	31	3.04	24	4.66	6	3.61	2.14
Chongqing	19	1.86	9	1.75	1	0.60	2.25
Guizhou	20	1.96	17	3.3	5	3.01	2.71
Shanxi	12	1.18	7	1.36	3	1.81	2.78
Fujian	149	14.62	142	27.57	6	3.61	2.88
Shaanxi	35	3.43	23	4.47	4	2.41	2.91
Heilongjiang	22	2.16	17	3.30	5	3.01	2.98
Liaoning	49	4.81	36	6.99	5	3.01	3.41
Jiangxi	17	1.67	12	2.33	4	2.41	3.47
Yunnan	26	2.55	11	2.14	6	3.61	3.58
Guangxi	31	3.04	15	2.91	10	6.02	3.59
Zhejiang	21	2.06	10	1.94	10	6.02	4.24
Hubei	44	4.32	30	5.83	8	4.82	4.46
Anhui	39	3.83	16	3.11	4	2.41	4.64
Hunan	35	3.43	32	6.21	3	1.81	5.12
Hebei	22	2.16	4	0.78	5	3.01	5.60
Jiangsu	21	2.06	13	2.52	5	3.01	6.13
Sichuan	104	10.21	18	3.50	18	10.84	6.26
Henan	30	2.94	12	2.33	26	15.66	7.32
Shandong	28	2.75	15	2.91	12	7.23	7.47
Guangdong	193	18.94	5	0.97	7	4.22	8.13
Total	1,019	100.00	515	100.00	166	100.00	100.00

Source: Authors' calculation based on NBS (2011) population share data. Other data derived from Talhelm et al. (2014) and are available at http://www.openicpsr.org/repoEntity/show/5455.

Note: Dashes indicate no observations in that province.

The experiment on implicit individualism covers 515 subjects. Fujian province dominates the sample with 142 observations, constituting 27.57 percent of the total sample size. By contrast, only 1 and 2 students were surveyed in Qinghai and Shanghai, respectively. The small sample size makes it impossible to draw a strong inference in these provinces. The sample size for the loyalty nepotism experiment is much smaller at 166. There is only 1 observation in three provinces (Ningxia, Shanghai, and Chongqing). Since the share of the cultivated rice paddy area is measured at the province level, the results on the relationship between rice area and the three outcome variables hinges crucially on spatial variations across provinces. The uneven distribution of sample sizes across provinces, in particular the extremely small number of observations in some provinces, may result in spurious estimates. To check if it is the case, we first replicated the results of Talhelm et al. (2014) based on their original sample and then dropped provinces with more than 100 observations in regressions on holistic thought and implicit individualism and provinces with fewer than 5 observations in regressions on loyalty/nepotism.

Table 2.2 presents the regression estimates. Regressions R1, R5, and R11 successfully replicate the original regressions for the three outcome variables. The three outcome variables are holistic thought, implicit individualism, and loyalty/nepotism, taken from Talhelm et al. (2014). Holistic thought is measured by a triad task in which participants pair two out of three items through either abstract or functional relationship; individualism is measured as the difference in the circles of friends and self in a self-drawn social network; the variable of loyalty/nepotism measures whether people draw a sharp distinction between how they treat friends and how they treat strangers. The rice variable is defined as the percentage of cultivated land devoted to rice paddies. It is significant in all three regressions with the expected sign. Regressions R3, R7, and R13 repeat the corresponding regressions in regressions R1, R5, and R11, except they drop either the oversampled provinces (more than 100 observations) or the undersampled provinces (fewer than 5 observations). In the regression on holistic thought (R3), the rice variable remains highly significant after dropping the oversampled provinces. With respect to implicit individualism, the significance level for the rice coefficient declines from 1 percent in regression R5 to 10 percent in R7 after removing Fujian from the sample. The result on loyalty/nepotism is more sensitive. After excluding the provinces with fewer than 5 observations, the rice coefficient becomes insignificant, as shown in regression R13. In short, the uneven sampling size distribution does affect the regression results.

Table 2.2 Robustness checks of Talhelm et al. (2014) on holistic thought, implicit individualism, and loyalty/nepotism

	Holistic thought				Implicit individualism						Loyalty/nepotism			
	Whole sample		Drop sample size > 100		Whole sample		Drop sample size > 100		New measurement		Whole sample		Drop sample size < 5	
Variable	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**
Gender	0.20***	0.12*	0.30***	0.27***	–0.13**	–0.11**	–0.09	–0.06	–0.06*	–0.06*				
	(0.06)	(0.07)	(0.07)	(0.08)	(0.05)	(0.05)	(0.06)	(0.06)	(0.03)	(0.04)				
Site	–0.34***	–0.39***	–0.47***	–0.54***	–0.27***	–0.21***	–0.28***	–0.22***	–0.11***	–0.09**	1.96**	2.30***	2.57***	2.50***
	(0.11)	(0.12)	(0.12)	(0.14)	(0.05)	(0.06)	(0.06)	(0.06)	(0.03)	(0.04)	(0.83)	(0.87)	(0.84)	(0.91)
Rice	0.54***	0.44*	0.52**	0.36	–0.20***	–0.14	–0.17*	–0.12	–0.06	–0.03	2.57**	1.45	1.73	0.13
	(0.21)	(0.23)	(0.24)	(0.26)	(0.08)	(0.09)	(0.11)	(0.11)	(0.05)	(0.06)	(1.20)	(1.34)	(1.25)	(1.64)
Per capita gross domestic product		0.13		0.24		0.19		0.21		0.03		1.41		0.06
		(0.30)		(0.32)		(0.17)		(0.18)		(0.11)		(2.09)		(3.16)
Pathogens		–0.20		–0.17		0.06		0.07		0.03		0.18		–0.74
		(0.12)		(0.13)		(0.06)		(0.06)		(0.04)		(0.79)		(0.88)
Participants	1,019	728	573	475	515	452	373	310	511	448	166	138	139	115
Provinces	28	21	25	19	28	21	27	20	28	21	27	21	16	13

Source: Authors creation based on data from Talhelm et al. (2014).

Note: Similar to Talhelm et al. (2014), we run hierarchical linear modeling. The binomial option is used in holistic thought. Standard errors are in parentheses. The Site variable represents dummy of SiteFujian, dummy of SiteBeijingW2011, and dummy of SiteSichuan in holistic thought, implicit individualism, and loyalty/nepotism, respectively. These dummies reflect the places where different experiments were conducted. See Talhelm et al. (2014) for details. *p < .1. **p < .05. ***p < .01.

3. MODEL MISSPECIFICATION

One key objective of the Talhelm et al. (2014) study is to dismiss two other popular competing theories—the modernization hypothesis and pathogen prevalence hypothesis. The authors used per capita gross domestic product (GDP) to measure the impact of modernization and disease rates in earlier years to measure the precontemporary disease prevalence. The paper tested the three hypotheses independently by running three separate regressions. In principle, a more rigorous test should include all three key variables of interest in the same regression and examine their relative importance to the outcome variables. As a matter of fact, the paper later included both rice and per capita GDP when testing the impact of rice faming on innovations.

In Table 2.2, we added per capita GDP and pathogens in all the regressions based on both the original sample and the restricted samples. The results are shown in the columns marked with even numbers after the capital letter *R.* As shown in regression R2, after controlling for the two variables, the rice variable remains significant in the regression on holistic thought based on the whole sample. However, the significance level of the rice coefficient drops to 10 percent. Once the provinces with more than 100 observations are dropped from the sample, the rice variable in the augmented regression (R4) loses its significance. Regardless of the whole sample or restricted sample being used, the rice variable in augmented regressions on implicit individualism (R6 and R8) is insignificant. Also insignificant is the rice coefficient for the outcome variable of loyalty and nepotism as shown in regressions R12 and R14. When evaluating the three competing hypotheses simultaneously, the rice story does not exhibit any stronger explanatory power on the psychological differences than the modernization and pathogens mechanisms. In fact, none of them matters to the observed psychological differences.

4. MEASUREMENT ERRORS

The experiment on implicit individualism was likely subject to measurement errors. The experiment was conducted as follows, according to Talhelm et al. (2014, 606): "Researchers measure how participants draw a diagram of their social network, with circles to represent the self and friends. 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)."

The difference between the width of self circles and the width of friend circles was used as a measure of implicit individualism. Since the experiments were undertaken in different times and different locations, there might exist systematic differences in survey instruments (pencil and paper) across sites. For example, the width of self circles among the 193 subjects surveyed in the winter of 2011 in Beijing averaged at 1.97. The experiment on 318 observations in other places revealed an average of 1.26. The two mean values are statistically different at the 1 percent level.

Even for subjects originally from the same province, scores varied greatly if measured in different places and times. For instance, the subjects from Heilongjiang province measured in the winter of 2011 in Beijing (sample size of 9) reported an average width of self circles of 1.27. In comparison, the average width of self circles among the subjects from Heilongjiang measured outside Beijing was as high as 1.97. The two samples exhibit a large difference (with a p value of .000). The two experiments (sample sizes of 19 and 10) conducted in Hubei province at different times scored 1.29 and 2.12, respectively. The p value testing the mean difference between the two samples is .002. The average width of self circles reported in two separate experiments (sample sizes of 18 and 13) in Hunan province is 1.29 and 2.12, and the difference is statistically significant at 0.2 percent. If there were systematic measurement errors on the width of self circles across space and over time, the variable of implicit individualism (the difference between the width of self circles and the width of friend circles) would automatically have embedded measurement errors, making it incomparable across sites. One way to remedy the problem is to use relative difference between the width of self and friend circles, that is, the ratio of the difference between the width of self and friend circles to the width of self circles.

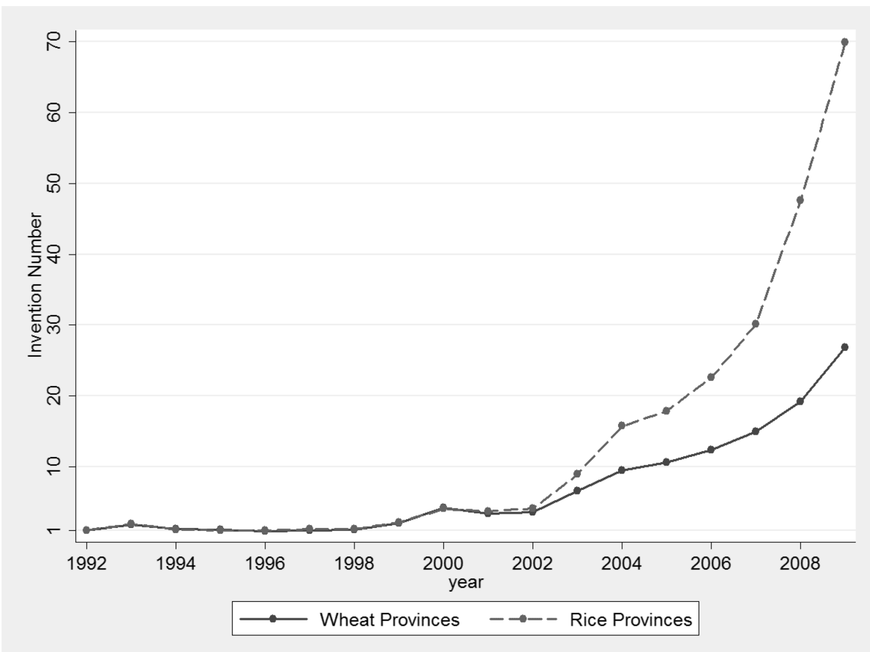
Regressions R9 and R10 in Table 2.2 report the estimates on the new measure of implicit individualism. No matter whether per capita GDP and pathogens are included or not, the rice variable plays an insignificant role in determining implicit individualism measured in a new way. Correcting the measurement errors makes a big difference to the main results.

5. PATENTS

It has been found in the literature that analytical thinking skills are more instrumental for facilitating innovation than is holistic thinking (Witkin et al. 1977). According to the rice theory, people in wheat-cultivating areas are more skilled in analytical thinking, whereas those in rice-producing regions are more inclined toward holistic thinking. Therefore, people in wheat-cultivating areas are expected to show stronger creativity than their counterparts in rice-cultivating areas. Based on cross-province patents for inventions in 1995, Talhelm et al. (2014) showed that there is indeed a negative association between the number of invention patents and the share of land devoted to rice paddy.

However, the analysis is subject to several flaws. First, the results do not hold for later years. Figure 5.1 plots the accumulative growth rate of invention patents in the rice- and wheat-cultivating areas by year, with the initial year, 1995, as 1. It is apparent from the figure that the number of invention patents in the rice-producing areas has grown more rapidly than that in the wheat areas, contradictory to the prediction of the rice theory.

Figure 5.1 Accumulative growth of invention patents in rice and wheat provinces



Source: Authors' calculation based on State Intellectual Property Office (2014) granted invention patent data at the provincial level.

Panel A in Table 5.1 presents the regression estimates for granted invention patents per capita in different years. The first column replicates the results for 1995, as reported in the original paper. Indeed the rice variable is negative and significant, consistent with the prediction of the rice theory. However, when repeating the exercise for 1999, 2005, and 2009, the coefficient for rice is no longer significant for 2005 and 2009. In 2009, the rice variable even turns positive, albeit insignificant.

Table 5.1 Rice farming and patents

	Invention per capita (log)					Total patents per capita (log)					Inventions per capita (log) (excluding schools)				
	R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**
	1995	**1999**	**2005**	**2009**	**1992–2009**	**1995**	**1999**	**2005**	**2009**	**1992–2009**	**1995**	**1999**	**2005**	**2009**	**1992–2009**
Panel A: Number of granted patents according to the year of approval															
Rice	–1.20***	–1.25***	–0.42	0.14	–0.43	–0.64**	–0.11	0.49*	0.66**	0.39					
	(0.38)	(0.30)	(0.26)	(0.29)	(0.27)	(0.28)	(0.25)	(0.28)	(0.29)	(0.24)					
Panel B: Number of granted patents according to the year of submission															
Rice	–1.18***	–0.98***	–0.09	0.18	–0.19	–0.51*	–0.05	0.53*	0.61*	0.43*	–0.34	–0.1	0.79	1.13	0.47
	(0.32)	(0.27)	(0.27)	(0.30)	(0.26)	(0.27)	(0.26)	(0.28)	(0.30)	(0.24)	(0.63)	(0.57)	(0.62)	(0.68)	(0.59)
Observations	27	27	27	27	486	27	27	27	27	486	27	27	27	27	486

Source: Authors' calculation based on State Intellectual Property Office (2014), NBS (various years), and Talhelm et al. (2014).

Note: The dependent variables in Panel A are the number of granted patents by year, available from the State Intellectual Property Office. The dependent variables in Panel B are the number of granted patents corresponding to the application year. The two variables are not identical because it takes several years to process patent applications. We computed the number of patents according to the year of application at the provincial level using the raw patent data applied from 1985 to 2009. The dependent variable in regressions R11 through R15 is the number of granted invention patents that were not applied for by universities and research institutions. The total number of patents includes the number of invention, utility model, and design patents. Per capita gross domestic product (GDP) is controlled in the regressions. GDP and population data can be downloaded from http://www.stats.gov.cn. Rice data are provided in Talhelm et al. (2014) and are available at http://www.openicpsr.org/repoEntity/show/5455. We used ordinary least squares to estimate cross-sectional regressions and the random effect model to estimate panel regressions. We included year dummies to control for systematic temporal variations in the panel regressions. The number of observations in R5 and R11 is 483 instead of 486 because there are three observations having zero inventions, which are dropped after log transformation. Standard errors are in parentheses. $*p < .1$. $**p < .05$.$***p < .01$.

China's patent law was not put into effect, and the State Intellectual Protection Office did not accept patent filings, until 1985. Since it took on average 3 to 6 years to process invention applications, the number of approved invention patents in the first 10 years is rather low compared to later periods. For example, the number of granted invention patents in the period from 1985 to 1995 accounts for about 5 percent total granted invention patents during the period from 1985 to 2009. Specifically, the number of approved invention patents in 1995 amounts to merely 0.6 percent of total patents. So it is less accurate to use the patent number in 1995 as a measure of innovation capacity than numbers in later years.

Although the regressions have controlled for per capita GDP, the cross-province analyses are subject to the problem of omitted factors, such as education level and innovation promotion policies. To partly address this concern, we further conducted a regression on a panel dataset covering the same 27 provinces from 1992 to 2009. In the panel regression, we included year fixed effects to control for some systematic shift in macro policies. Because the rice variable does not change over time, we could not directly include province fixed effects. Instead, we assumed a random effect across provinces in the regression. The rice share in the panel regression is not statistically significant.

Second, Talhelm et al. (2014) use only invention patents. Although invention patents may embody more technological innovations, doubtless the patents for utility model and design are also the children of creativity. In 2009, invention patents accounted for only 22 percent of total patents, while patents for utility model and design constituted 42 percent and 37 percent, respectively. So invention patents are just a small portion of total patents. It is import to check if the results in panel A are robust to the inclusion of patents for utility model and design. We repeated the previous exercises in panel A by replacing invention patents per capita with total number of patents per capita as a dependent variable. Regressions R6 through R10 in panel A of Table 5.1 display the regression results on the new outcome variable. The rice variable in regression R6 in 1995 is –0.64 and is statistically significant. In 1999, although it is still negative, it loses significance. For the cross-province regressions on 2005 and 2009, the rice coefficient turns positive and significant. The rice variable in the regression on the panel of 1992–2009 is also positive and marginally significant. The positive rice coefficient in regressions R8 through R10 in both panels contradict the rice hypothesis.

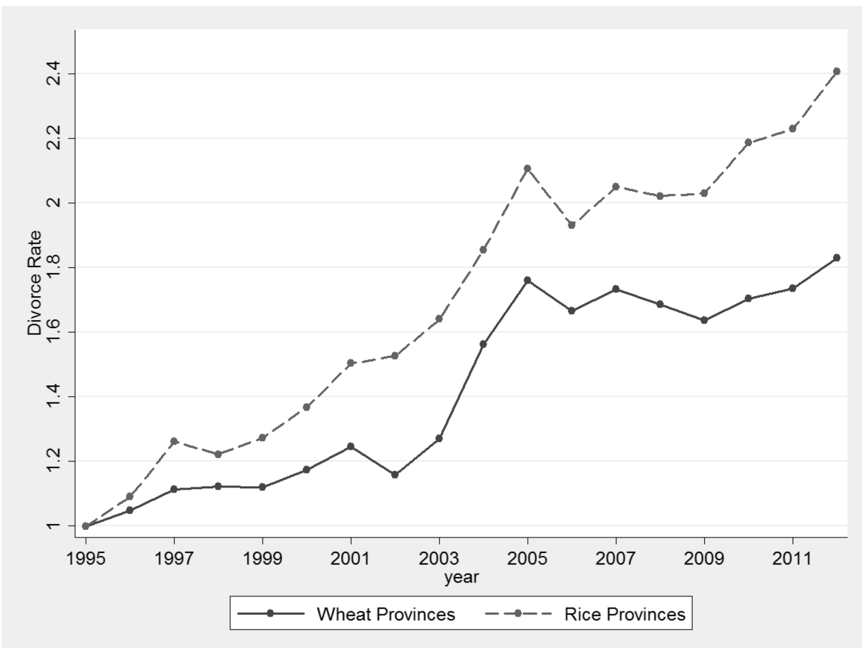
Third, there is a long time lag, up to six years from submitting a patent, for receiving an approval. In the original paper, the authors control for per capita GDP in the same year as the patents granted. However, the number of granted patents actually represents the innovation level several years back at the time of submission, not the level at the year of approval. The observed positive association between GDP and number of patents may run the other way around—it is the high innovations that contribute to GDP growth. Due to the potential reverse causality, it is problematic to use both patents granted and GDP at the year of approval. Having access to all the patent entries, we were able to compute the number of patents based on the year of submission, and we used it as a dependent variable. We repeated all the regressions in panel A, except for using the new patent variable, and presented the estimates in panel B. The results in panel B resemble those in Panel A. The rice variable does not have a consistent sign across regressions, largely rejecting the rice hypothesis.

Fourth, applicants for patents may not come from the provinces where the patents are filed. In China, universities and research organizations filed about 30 percent of invention patents, and many researchers in these institutions came from elsewhere. So the number of granted invention patents in a province may not truly reflect the innovation capacity of the province's indigenous people. As a robustness check, we excluded the number of invention patents filed by universities and research organizations in the outcome variable and reported the regression results in panel B (R11–R15). None of the coefficients for rice is significant in the five regressions. It is even positive in three of the five regressions, in contrast to the prediction of the rice theory.

6. DIVORCE RATE

It has been shown in the literature that individualistic countries exhibit higher divorce rates (Lester 1995). Since the rice theory predicts higher individualism in wheat regions than in rice regions, the rice theory also predicts a higher divorce rate in wheat-producing regions because of their strong individualism. The rice paper provides some supportive evidence using data from 27 provinces in 1996.[1] In the paper, the divorce rate is measured as the ratio of divorces to new marriages in each year and province. If the rice theory holds, we would expect to see the same pattern in later years as cultural preferences change slowly. To check this out, we first plotted divorce rates in the rice and wheat regions from 1995 to 2012 in Figure 6.1. In the figure, we normalized the divorce rate by the initial year value. As shown in the figure, the divorce rate in the rice-cultivating areas has grown much faster than that in the wheat-growing areas, contrasting the prediction of the rice hypothesis.

Figure 6.1 Divorce rates in rice and wheat provinces



Source: Authors' calculations based on NBS (various years) annual number of divorces and marriages at the provincial level.
Note: Following Talhelm et al. (2014), divorce rate is defined as the ratio of the number of divorces to the number of marriages. We normalized the rate by the initial value in 1995.

The evidence in the figure is just suggestive as it does not control for other confounding factors. Table 6.1 presents the regressions of divorce rate on the rice variable by controlling for per capita GDP. Regressions R1, R2, and R4 replicate the results in the original paper. The significant rice variable in the regressions on 1995 and 1999 confirms the findings in the original paper. But the coefficient in the regression on 2009 is not significant, unlike what is claimed in the paper. To check the robustness of the results for later years, we run regressions on 2005 and 2012. The rice variable is significant in regression R3 (2005), but not in R5 (2012). It seems that over time the association between rice farming and divorce rate weakens. When pooling all the years together and running a panel regression in R6, the coefficient for rice is no longer significant.

[1]The data are actually from 1995. The authors claimed that the results are robust for 1999 and 2009. However, the regression results are not available from the article and supplementary materials.

Many divorced people get remarried. Thus, using the ratio of divorces to marriages as a measure of divorce rate likely underestimates the true divorce rate. The official divorce rate in China is defined as the ratio of divorces to total population. We repeated the above analyses using the official divorce rate and showed the results in regressions R7 through R12. The basic patterns remain. The negative association between rice area share and divorce rate is significant only in earlier years (1995 and 1999), not in later years. Compared to regression R3, the rice variable is no longer significant in 2005 (R9) when using the official divorce rate. Above all, the legacy of rice farming on divorces fades over time.

Table 6.1 Rice farming and divorce rate

	Divorces per marriage						Divorces per capita					
	1995	1999	2005	2009	2012	1995–2012	1995	1999	2005	2009	2012	1995–2012
Variable	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**
Rice	–0.11***	–0.11**	–0.10*	–0.06	–0.06	–0.06	–0.76***	–0.66**	–0.47	–0.29	–0.42	–0.36
	(0.04)	(0.04)	(0.06)	(0.05)	(0.05)	(0.05)	(0.26)	(0.25)	(0.32)	(0.38)	(0.44)	(0.30)
Gross domestic product per capita	0.12***	0.09***	0.04**	0.02*	0.02**	–0.00	0.67***	0.55***	0.23**	0.13*	0.07	–0.02
	(0.03)	(0.02)	(0.02)	(0.01)	(0.01)	(0.00)	(0.24)	(0.13)	(0.09)	(0.08)	(0.07)	(0.02)
Observations	27	27	27	27	27	486	27	27	27	27	27	486

Source: Authors' calculations based on NBS (various years) and Talhelm et al. (2014).

Notes: Population, marriage, and divorce data are available at http://www.stats.gov.cn. Divorces per marriage are defined as the number of divorces divided by the number of new marriages for each year and province as in Talhelm et al. (2014). The variable of divorces per capita is defined as the number of divorces divided by population for each year and province, a standard definition of divorce rate. Regressions R1, R2, and R4 are replications for regressions mentioned in Talhelm et al. (2014). Regressions R3, R5, R6, and R7 through R12 are robustness checks. We used ordinary least squares to estimate cross-sectional regressions and the random effect model to estimate panel regressions. We included year dummies to control for systematic temporal variations in the panel regressions. Standard errors are in parentheses. *p < .1. **p < .05. ***p < .01.

7. TESTING THE RICE THEORY USING OTHER DATASETS

In the previous sections, we have tried to replicate and verify the main results using data from the original paper. There are alternative ways to measure collectivism and individualism in the literature. It is worth testing the rice theory using alternative measures. Van de Vliert et al. (2013) surveyed 1,663 subjects in 15 Chinese provinces. Their sample size in each province largely corresponded to its population size. Based on a 14-item measure of psychological attributes associated with collectivism, they constructed a composite indicator of collectivism and computed average collectivism scores at the provincial level. They further imputed the collectivism scores for the other 19 provinces in China. They found that the wheat-producing Heilongjiang Province exhibits the highest degree of collectivism, while the rice-producing Guangdong Province scores the lowest in collectivism.

Using their collectivism measure in the 15 provinces, we conducted three regressions and reported the estimates in Table 7.1. The first regression (R1) includes only rice as an independent variable. The negative and significant coefficient for the rice variable indicates that rice farming is associated with a lower degree of collectivism, confronting the rice theory. In the second regression, we added per capita GDP. The rice variable remains significantly negative. In the third regression, we further controlled for pathogen. The rice variable is still negative. Because of the small sample size, the results should be read with caution. To ameliorate the concerns on the small sample, we repeated the three regressions by adding provinces with imputed collectivism scores into our sample. The rice variable is now statistically significant in all three regressions. The negative rice coefficient across the three regions directly challenges the rice hypothesis.

Table 7.1 Rice and alternative measure of collectivism

	Observed collectivism			Estimated collectivism		
Variable	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
Rice	–0.16**	–0.17*	–0.20	–0.19***	–0.19***	–0.17**
	(0.06)	(0.08)	(0.13)	(0.06)	(0.06)	(0.08)
Per capita gross domestic product		0.06	0.20		–0.02	–0.06
		(0.14)	(0.34)		(0.06)	(0.09)
Pathogens			0.02			–0.02
			(0.08)			(0.05)
Observations	14	14	11	28	28	21

Source: Data on observed and imputed collectivism at the provincial level are from Van de Vliert et al. (2013). Other data are from Talhelm et al. (2014).

Note: Standard errors are in parentheses. *$p < .1$. **$p < .05$. ***$p < .01$.

It has been shown in the psychological literature that family structures have something to do with collectivism (Vandello and Cohen 1999). In regions with strong collectivism, extended families with more than two generations are more prevalent. Vandello and Cohen (1999) and Yamawaki (2012) have used the share of extended families with three or more generations as one of the indicators in constructing a composite measure of collectivism in the United States and Japan, respectively.

The China Population Census in 2010 includes detailed information about family structure. We used the share of extended families with more than two generations in total families at the provincial or county level obtained from the 2010 census as a measure of collectivism. For the provincial-level regressions, we followed the same specifications as in Table 7.1. For the county-level regressions, we used hierarchical linear modeling regressions because the rice and pathogen variables are at the provincial level. Table 7.2 reports the regression results based on provincial and county-level data, respectively. First, in regressions R1 and R4, we included only the rice variable. The rice coefficient is not significant. Second, we added per capita GDP in regressions R2 and R5. The rice variable remains insignificant. Last, we further included pathogen. The rice coefficient is largely the same. The per capita GDP variable, a measure of modernization, is negative and statistically significant whenever it is included in regressions. The finding lends more support to the modernization hypothesis rather than the rice hypothesis.

Table 7.2 Rice and the percentage of extended families

	Share of extended families					
	Province analysis			County analysis		
Variable	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
Rice	0.01	0.02	0.03	0.02	0.03	0.04
	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)
Per capita GDP 2010		–0.02***	–0.02***		–0.02***	–0.02***
		(0.00)	(0.01)		(0.00)	(0.01)
Pathogens			–0.01			–0.01
			(0.01)			(0.01)
Observations	28	28	21	2,582	2,582	2,110
Number of provinces	28	28	21	28	28	21

Source: Authors' calculations based on China Population Census (NBS 2010), China Statistical Yearbook (NBS 2011), and Talhelm et al. (2014).

Note: GDP = gross domestic product. The extended family is defined as a household with at least three generations. The ratio of extended families to total families at the provincial or county level is computed by authors based on China Population Census (2010). Per capita GDP in 2010 is from China Statistical Yearbook (2011). We did not take log of per capita GDP 2010 to keep consistent with Talhelm et al. (2014). The variables of rice and pathogens are from Talhelm et al. (2014). We used ordinary least squares to estimate regressions R1 through R3 and hierarchical linear modeling to estimate regressions R4 through R6. Standard errors are in parentheses. ***$p < .01$.

8. CONCLUSION

The innovative rice theory proposed by Talhelm et al. (2014) has attracted wide media and academic attention. This study attempted to test the robustness of the popular theory. We first used the original dataset from the paper to replicate and verify its main results. We found that the findings are subject to sample bias, measurement errors, and model misspecifications. After correcting these problems, their main findings no longer hold. We further used alternative collectivism measures as an outcome variable and again failed to validate the results. Overall, we found that the rice theory is not as robust as claimed by the original article.

The rice theory also offers a few clear testable predictions on the trends of patents and divorce rates between rice and wheat provinces. The rapid transformation in China in the past several decades provides a ground to directly test the predictions. In contrast to the predictions of the rice theory that collectivism and holistic thinking embedded in rice culture inhibit creativity and innovation, it turns out that the rice-cultivating areas, such as the Pearl River delta and Yangtze River delta regions, have witnessed a much faster growth in securing patents than the wheat-producing areas. Moreover, despite the supposed culture of valuing cooperation and collectivism, the rice provinces have experienced a more dramatic spike in divorce rate than wheat regions in the past two decades.

The legacy of rice farming on cultural preferences, if there is any, has not shown itself to be as robust as desirable. China is affected by many cultural winds, both modern and historical, and the influence of rice farming is only one. Although the findings presented in Talhelm et al. (2014) seem to be tenuous, the ingenuity of the hypothesis will, it is hoped, continue to spark investigation into causal factors for cultural differences.

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