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Can traditional farming practices explain attitudes towards scientific progress?

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A B S T R A C T

Recent studies have shown that agricultural legacies can have a lasting effect on cultural formation. However, to date, the literature has not examined how the agricultural origins of culture affect individual preferences for modern technology. This paper addresses this gap by investigating how the agricultural origins of individualist and collectivist cultures have affected individual attitudes towards contemporary science and technology, at the subnational level. Its results suggest that societies that have historically cultivated low labor-intensive crops, which demand individualistic behavior, have developed favorable attitudes towards technology. Conversely, societies that cultivated labor-intensive crops, which required intense cooperation and cohesiveness among farming communities, developed collectivist norms, which in turn led to their exhibiting a lower affinity to, and preference for, technology. This study's findings advance our understanding of how the diversity of agricultural legacies can explain subnational differences in individual's attitudes towards modern scientific progress.

1. Motivation

One of the central questions in economics is why the industrial revolution took place in Northern Europe and not in China or the Middle East. In response, researchers have suggested that the deep-seated cultural differences between the East and the West have exacerbated their technological and income divergence (Tabellini, 2010; Alesina and Giuliano, 2015; Gorodnichenko and Roland, 2017).

Western cultures are strongly individualistic. They are characterized by individual autonomy, self-reliance, freedom of choice, and risk-taking behaviors (Sampson, 1988; Markus and Kitayama, 1991a; Snibbe and Markus, 2005; Kitayama et al., 2006; Gorodnichenko and Roland, 2012), all of which motivate individuals, with unique and novel ideas, to create and adopt innovative technologies. Conversely, eastern cultures are more collectivist (Talhelm et al., 2014b). They stress loyalty, respect of traditions, group conformity, solidarity, interdependence, and obedience (Triandis, 1995; Brewer and Chen, 2007), all of which compel individuals to resist change, creativity, new ideas, and technologies.

Historically, researchers have used dichotomies between individualistic and collectivist cultures to explain cross-country variations in economic development and technological innovation and diffusion (Shane, 1992, 1993; Mokyr, 2002; Tabellini, 2010; Gorodnichenko and Roland, 2017; Taylor and Wilson, 2012; Fogli and Veldkamp, 2012; Spolaore and Wacziarg, 2009). The literature also recognizes that a relationship exists between individualism and innovation production (Gorodnichenko and Roland, 2011).

Because this paper concerns individual attitudes towards science and technology, some further explanation is required of how these cultural norms provoke diverse preferences concerning technology. Accordingly, individualism and collectivism commonly refer to the distinction between self-interest and group-interest. However, Edison and Geissler (2003) described five personality traits that stimulate positive attitudes towards technology (see Section 2, page 6 for more detail of this), and which enrich the fundamental characteristics of individualistic and collectivist cultures far beyond the common "I" versus "we" dichotomy (Schwartz, 1990; Triandis, 1995; Hofstede et al., 2010; Mokyr, 2002).

However, although Edison and Geissler (2003) hinted at a potential link between individualism and positive attitudes towards technology, the underlying factors that might have explained these differences remain unclear and are not empirically tested. Thus, a broader investigation is required, to be able to assert that cultural formations provoke different perceptions of technology.

The use of direct measures of individualism or collectivism, as commonly used in the literature, would risk introducing endogeneity bias into the research, since advances in technology could influence the values and cultural norms of societies. Instead, the paper draws on Talhelm and colleagues' (2014) *rice theory of culture*, to analyze the implications of historical farming practices on individualistic or collectivist

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cultural norms, as well as its impact on individual attitudes towards science and technology.

Researchers have shown that irrigation intensity and labor requirements influence societies' collective effort (Mann, 1986; Talhelm et al., 2014; Buggle, 2020). In arid climates, labor-intensive crops, such as rice, require complex irrigation systems to distribute water to them. Furthermore, these irrigation systems require collective construction, maintenance, and coordination to ensure optimal water delivery during water cycles (Janssen, 2007; Talhelm, 2018). The cultivation of labor-intensive crops is an arduous process that requires strong coordination within farming communities, to organize seeding, transplanting, pest control, and harvesting dates. In order to maximize their individual welfare, farmers must cooperate and form close relationships with their fellow farmers, rather than straying from collective efforts. Thus, cooperation, conformity, obedience, and cohesion are the crucial characteristics of societies that are dependent on labor-intensive crops (Buggle, 2020). Consequently, collectivist cultural norms arise from environments that value collective effort.

Conversely, low labor-intensive crops, which are irrigated by rainwater, require little to no coordination with fellow farmers. Thus, individualistic cultural norms appear in environments where agricultural conditions favor low labor intensity, low interdependence, and individual autonomy.

However, although Talhelm et al. (2014) influential *rice theory of culture* tested this phenomenon empirically, using China as its testing ground, the study was limited to only a small number of regions within China. The researchers concluded that the rice-growing south of China had a collectivist culture, whereas the wheat-growing north of China was more individualistic. Furthermore, the researchers' findings cannot be generalized to the rest of the world, since most European countries do not farm rice.

Other researchers shifted their focus from the rice-wheat dichotomy. For example, Ang (2019), used several crops to create a single index, that measured the labor intensity of farming environments by aggregating labor intensity and caloric yield of seven major crops. His cross-country study found that labor-intensive farming environments were associated with less individualistic cultures today (Ang, 2019). Similarly, collectivist cultural norms emerged in societies that had a history of practicing irrigation agriculture (Buggle, 2020). Thus, one can safely state that the literature supports a well-established link between labor-intensive crop cultivation and cultural orientation towards individualism.

Even though this paper's underlying principles are similar to the above research, I diverge from them in three important ways. First, I focus primarily on hypothesizing and, thereafter, establishing the relationship between the agricultural origins of individualist/collectivist cultural norms and individual attitudes towards contemporary technology. I use a two-step approach to achieve this. I begin by demonstrating that historical farming practices engender individualistic and collectivist cultural norms. Although this has already been established at the cross-country level, I add to the literature by affirming this relationship at a global, subnational level. Following that, I investigate how the agricultural origins of both cultural norms affect attitudes towards science and technology. My first hypothesis assumes societies nurtured favorable attitudes towards technology through the individualistic behavior that stemmed from agronomics, which required low labor-intensive crop production. That is, a legacy of farming individualism-enhancing crops has a positive effect on modern day attitudes towards technology. My second hypothesis postulates that societies, which cultivated high labor-intensive crops, are collectivist and, thence, will demonstrate a lower affinity towards technology. That is, a legacy of farming collectivism-enhancing crops has a negative effect on individual attitudes towards technology. The results of this latter investigation will constitute a major contribution to the literature, as no earlier study has investigated the link between cultural norms and individual attitudes towards technology.

Second, and unlike Ang (2019), I use two separate indices to capture individualistic- and collectivist-enhancing environments. In my opinion, this enables a distinction to be made between the two cultures, and it identifies their impacts on attitudes.

Third, I focus on the variations at the subnational level. Talhelm et al. (2014) established the existence of rice-wheat cultural differences between different regions, but within a single country. However, by aggregating crop measures at the country-level, Ang (2019) may have overlooked the important cultural patterns that evolve within subnational regions.

Against this backdrop, this paper tests whether favorable attitudes towards science and technology (S&T) emerge in societies that have a history of cultivating low labor-intensive crops (individualistic-enhancing crops) as compared to societies that have cultivated labor-intensive crops (collectivist-enhancing crops). The paper's central premise is that cultural traits are formed by long-term exposure to specific types of crop cultivation, and can be traced to the labor requirements of crops. To test this, I create two separate indices for individualistic- and collectivist-enhancing crops, using historical land suitability data, for eight staple crops, from the Food and Agriculture Organization (FAO). I based my choice of crops on historical labor intensities, provided by the U.S. Department of Agriculture (1922), Lenhart (1945), and Cooper et al. (1916). I use attitudinal questions, related to S&T, taken from the World Value Survey (WVS) between 2010 and 2014 to empirically analyze the link between individualistic- and collectivist-enhancing crops and attitudes. I observed that positive attitudes towards technology emerged in individuals who came from a legacy of low labor-intensive crop cultivation. In contrast, individuals, who had a legacy of labor-intensive crop cultivation, showed a greater resistance to technology. These results are consistent at both the subnational and cross-country levels. Overall, the results consistently predicted that the agricultural origins of individualistic cultural norms had positive effects on modern-day attitudes towards science and technology, whereas those of collectivist cultural norms led to a lower affinity for technology.

This study further investigates the possible channels that lie beneath the results. Its analysis of second-generation migrant data reveals that parental transmission of culture is an important channel of cultural transmission. The paper also tests heterogeneous effects by gender. I find cultural transmissions to be similar across genders, for labor-intensive crops, because female participation in labor-intensive crop production is proportionately higher. Conversely, cultural transmissions were found to be stronger for men in low labor-intensive crop cultivation (where female participation in the crop production process was low). Other findings include the confirmation of a relationship between attitudes towards technology and comparative development, across countries.

This paper is structured as follows. Section 1 introduces the topic and describes the paper's motivation. Section 2 sets out the conceptual framework this paper will use to discover any potential links between individualism and positive attitudes towards technology. Section 3 describes the estimation strategy, data sources, and validity checks the paper used for its crop measures. Section 4 presents the results of the baseline model, followed by descriptions of the robustness checks, used to verify results. Section 5 makes a more in-depth investigation of the channels that lie beneath the results. Section 6 presents and comments on the study's additional findings, before Section 7 makes the paper's conclusions. Finally, the two appendices present the paper's data sources and some supplementary analyses.

2. Conceptual link between individualism and attitudes towards technology

The literature has clearly established that the labor intensity of crop cultivation leads to the formation of individualistic and collectivist cultural norms in societies. This study takes this understanding further, and claims that favorable attitudes towards technology are a result of societies with an agriculture legacy of cultivating individualism-enhancing crops. Crucially, and in order to do this, the paper must decipher the underlying mechanisms, which translate cultural norms and beliefs into various individual preferences or attitudes towards technology.

The literature of psychology defines an individual's attitudes as their general feelings of favorableness or unfavorableness towards an object (Ajzen and Fishbein, 1980). Furthermore, and as mentioned earlier, Edison and Geissler (2003) define five important individual characteristics or personal traits that they believed generated positive attitudes towards technology.

The first is *tolerance for ambiguity,* where an individual tends to perceive ambiguous situations as desirable. Because ambiguities stem from situations of uncertainty, multiple or unclear alternatives, and/or contradictions, they may cause some individuals to feel anxious and threatened; thus, diminishing their ability to reflect on and learn new concepts. Those individuals seek clear and well-defined norms, established structures, organizations, and institutions in order to feel secure in the presence of uncertainty. Conversely, individualistic cultures find joy and excitement in novelty, risks, and challenges (Schwartz, 1990), all of which enable individuals to be open to flexible structures. It encourages individualistic characters to be tolerant to risks and uncertainty, and thereby overcome complex, high-risk ambiguous nature of technology and show greater affinity towards technology in general.

The second trait is *dispositional optimism*. Optimists are individuals with self-confidence, who generally have positive expectations about their future. Heine and Lehman (1995), and Chang (2001) find that collectivist cultures are more pessimistic about future events. Further, Heine and Lehman (1995) postulate that the self-enhancement, promoted in individualistic cultures, leads to optimism, whereas the self-criticism, infused in collectivist cultures, breeds pessimism. Hence, positive expectations motivate individualistic characters to invest time and resources in new technology, to succeed, and achieve greater accomplishments in the future (Edison and Geissler, 2003). This translates into them exhibiting positive attitudes towards technology.

Third, Edison and Geissler (2003) identified the *locus of control* (or *internal control*) as an important personal trait that generates positive attitudes towards technology. Locus of control is defined as an individual's belief that they are in control of their actions (Rotter, 1966). Individualistic cultures value independence and personal accomplishment, which leads to personal control; whereas, in collectivist cultures, individual actions are governed by traditions, obedience, and conformity to one's group (Schwartz, 1990; Triandis, 1995; Markus and Kitayama, 1991). Hence, collectivist cultures exhibit characteristics of *external control*, perceiving new technology as something "less controllable (and less predictable), and may therefore be more threatening than it would seem to an internal." (Edison and Geissler, 2003).

Fourth is the *need for cognition*. Cacioppo et al. (1982) defined individuals as having either a high or a low need for cognition, i.e. the capacity to "engage in and enjoy effortful information (thinking)" (Edison and Geissler, 2003). Conversely, individuals with a low need for cognition avoid excessive-thought activities and information processing. Since collectivists prefer to conform to established structures, they would be unwilling to accept any additional complexity or information processing that deviates from the traditional. It follows that this low need for cognition will lead collectivist groups to exhibit a lower acceptance of modern technology.

Finally, Edison and Geissler (2003) identify individuals with greater *self-efficacy* as having a higher affinity towards technology. Self-efficacy is an individual's belief about their capabilities. An individual's competence and confidence in their ability makes them self-motivated. It enables them to control challenging and complicated environments, and increases their resilience to failure and the risks that are inherent to modern technology. Although Bandura (2001) finds that self-efficacy is not necessarily linked to individualism, other researchers confirm that individualistic societies value individual's competence, which enables them to be free and self-directed (Scholz et al., 2002; Schooler, 1990; Schwartz, 1990; and Wu, 2009). Hence, it is reasonable to consider self-efficacy, in individuals, leads to a positive affinity towards technology. In summary, the important personal traits of individualistic characters are a tolerance for uncertainty, optimism, self-control, an ability to process new knowledge, and self'-efficacy, all of which help to generate positive attitudes towards technology.

3. Data & empirical strategy

3.1. The regression model

Recall, the main objective of this paper is to test whether pre-industrial societies, that cultivated individualism-enhancing crops, have positive attitudes towards modern science and technology, where as those with a farming legacy of collectivism-enhancing crops show lower affinity towards technology. To test these two hypotheses, I used the following regression model;

$$Tech.Attiude_{ijkt} = \beta_0 + \beta_1 IDV.crops_{jk} + \beta_2 COLL.crops_{jk} + \beta_3 X_{ijkt} + \beta_4 Z_{jk} + \vartheta_k + \nu_t + \varepsilon_{ijkt} \tag{1}$$

where $Tech.Attiude_{ijkt}$ is the dependent variable that captures the attitude, towards science & technology, of individual i living in subnational region j of country k, who was interviewed in year t.[1] The independent variables $IDV.crops_{jk}$ and $COLL.crops_{jk}$ are the unweighted averages of the suitability indices of individualism- and collectivism-enhancing crops, respectively, at the subnational level. The vector X_{ijkt} controls for individual characteristics (i.e. age, age square, marital status, and gender) at the time of interview, and vector Z_{jk} controls for geographic and climatic conditions (i.e. landlockedness, mean elevation, distance to river, historical precipitation, historical temperature, and terrain roughness) at the subnational level. The baseline model also included country-fixed effects (ϑ_k) to control for country-specific heterogeneities and year-fixed effects (ν_t) to control for time variant differences at the subnational level.

3.2. Data

This section gives a detailed explanation of the variables used. Overall, the baseline sample consisted of 41,045 individuals from 46 countries, and covered 437 subnational regions. For detailed definitions of the variables, data sources, and descriptive statistics, please refer to Tables 1A, 2A and 3A in Appendix A.

3.2.1. Attitudes towards science and technology

The dependent variable is a measure of individual attitudes towards S&T. To discover this, I used seven questions from the World Value Survey, from between 2010 and 2014. They were, (1) science is important in daily life; (2) S&T makes life better; (3) S&T gives more opportunities to the next generation; (4) the world is better off with S&T; (5) the world depends too much on S&T; (6) science does not break people's ideas about right and wrong; and (7) competition is good to stimulate hard work and develop new ideas.

The first principal component of these seven questions captured the individual's attitudinal behavior towards technology. I matched the respondent's region, as indicated in the WVS, to the first-level administrative districts that were found in the Database of Global Administrative Areas (GADM). These regional boundaries were the same for crop measures (See Table 2A in Appendix A for the correlation between the first principal component and the seven individual questions.).

3.2.2. Individualism- and collectivism-enhancing crops

The study used eight crops to obtain separate measurements for

[1] Year t refers to the year in which the individual took part in the WVS. Hence, ν_t captures an interview year effect. The interview years vary only across countries, but not within a country.

individualism- and collectivism-enhancing environments. Since cultural traits are formed by long-term exposure to different systems of agricultural production, the choice of crops depended on historical labor intensities. A systematic list of historical labor usage was not available for all of the crops in the world; however, Table 1 summarizes the available historical labor intensities, for a variety of crops. The U.S. Department of Agriculture (1922) reported the number of man-hours,[2] per acre of land, for an extensive list of field crops. Potatoes, corn/maize, and field beans reported the highest labor intensities – among many other staple crops – and their man-hours per acre, exceeded 30. Studies by Lenhart (1945) and Cooper et al. (1916) also reported high labor intensities for these staple crops, in comparison to other crops. I avoided using varieties of pea crops in my analysis, because – and contrary to Lenhart (1945)'s findings – Fouka and Schlaepfer (2017) considered these low labor-intensive crops. The U.S. Department of Agriculture (1922), Lenhart (1945), and Cooper et al. (1916) all reported low labor requirements for alfalfa, wheat, oats, barley, rye, varieties of hay, sorghum, flax, timothy, and clove seeds. Additionally, I did not select cotton, corn silage, or hay crops to use in my main analysis, because fiber and fodder were not staple crops. Refer to Table 5A in Appendix A for the full list of crops available.

It is important to note that the above studies were carried out in the United States and; therefore, they do not include statistics about labor intensities for wetland rice production, because it is not commonly grown in the U.S. Nevertheless, Talhelm et al. (2014), Boserup (1965), Bray (1986), and Pimentel (2009) largely supported inclusion of rice as a high labor-intensive crop.

Based on the crop-specific labor intensities in Table 1 and the availability of data, I selected wheat, barley, oats, and rye as low-labor intensity, individualism-enhancing crops. I chose rice, corn (maize), potatoes, and beans as high labor intensity, collectivism-enhancing crops.

Although many other fruits, vegetables, fiber, and fodder crops were available, I restricted my selection to the above eight crops for several reasons. First, staple crops are more important for human survival and have been grown consistently for many centuries. Hence, cultural norms are more likely to emerge from staple crop production than from any other crop variety. Second, in 2002, the crops I selected accounted for approximately 65% of global production, in terms of the cultivated area (Leff et al., 2004). Third, these crops were rich in data, when compared to other crops. However, and as a robustness check, I expanded the number of crops to include sorghum and flax, as additional individualism-enhancing crops, and cotton and sugar beet, as collectivism-enhancing crops.

This study used the Global Agro-Ecological Zones (GAEZ, 2000) database, created by the FAO and the International Institute for Applied Systems Analysis (IIASA), to extract the crop suitability data of individual crops at the grid-level. It measured land suitability for a particular crop, by taking into account factors such as soil requirements, prevailing soil conditions, applied soil management, and a multitude of other ecological factors, for different periods (GAEZ, 2012). The suitability measures captured the mean climatic conditions for the period 1961–1990. I used crop suitability indices, under rain-fed conditions and at low farming input levels, to ensure that individualism- and collectivism-enhancing crop measures were sufficiently exogenous. Low farming input levels use only traditional cultivars with no application of nutrients or chemicals for pest and disease control, and adopt minimum crop conservation measures. The advantage of using crop suitability data, over actual crop production, is that it minimizes any potential issues of endogeneity, where technological improvements may have affected actual crop production, through cultural changes in attitudes towards technology. I mapped the GAEZ grid-level suitability data on to the first-level administrative boundaries in the GADM, to be able to compute the regional statistics for each crop, by taking the average over the specified boundaries. Fig. 1 a shows the crop suitability of wheat, mapped over the GADM's first-level administration districts within the United States. Fig. 1 b shows the average suitability index of wheat, for the first-level administrative districts used in the study. The measurement for the individualism-enhancing crops is the unweighted average of the suitability indices of wheat, barley, oats, and rye. Similarly, the collectivism-enhancing crop measurement is the unweighted average of the suitability indices for rice, corn (maize), potato, and beans. Table 4A in Appendix A provide summary statistics for the selected crops.

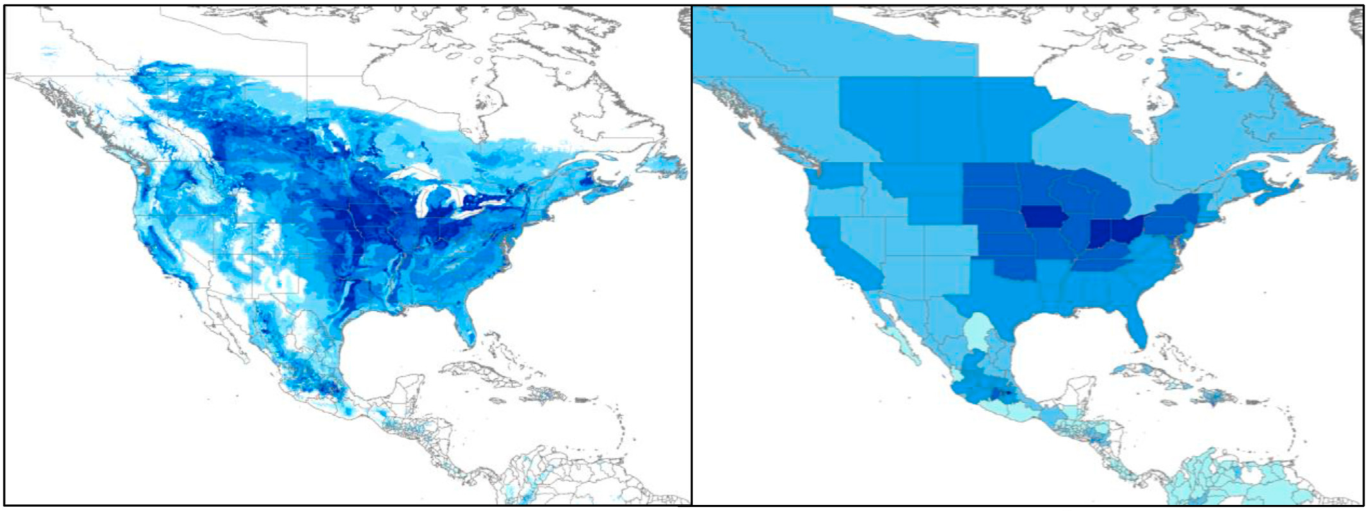
Table 1
Summary of crop specific labor intensities from different sources.

Crop	U.S. Dep. of Agriculture (1922) Man-labor hours, per acre	Lenhart (1945) Man-week of labor, per acre	Cooper et al. (1916) Labor hours, per acre	Fouka and Schlaepfer (2017) Labor shares from Prussian agri. data	Pimentel (2009) Labor hours per hectare (USA)
Apples	391.3				400
Tobacco	277.4				
Mangels			180.7		
Peas		3.0413		0.299	
Sugar beets	113.7	2.0857			
Cotton	114.7	1.7596			
Potatoes	**78.8**	**0.9888**	**44.4**	**0.571**	**35**
Corn silage	37.0		32.6		
Field beans	**35.0**			**0.601**	
Corn/ maize	**33.0**		**26.2**		**11.4**
Wetland Rice					**11**
Kafir and milo	19.8				
Alfalfa	17.8	0.3694			
Millet			17.3		
Rye	**17.1**		**10.3**	**0.149**	
Spring wheat	16.8				
Flax		0.0454	13.7		
Oats	**13.1**		**13.5**	**0.370**	
Barley	**12.3**		**12.8**	**0.079**	
Wild and grain Hay	11.4		12.2		
Clover Hay	10.4				
Wheat	**10.3**		**12.3**	**0.400**	**7.8**
Winter wheat	9.7				
Mixed tame Hay	8.5		12.3		
Timothy Hay	8.1				
Clover seed	7.2		9.2		
Timothy seed	6.6		5.1		
Sorghum		0.0500			

3.2.3. *Controls for individual and geographic characteristics*

The study controlled for a series of baseline covariates in order to isolate the farming-legacy effect from other individual and geographic characteristics. First, it controlled for individual characteristics, such as age, marital status, and gender. Next, the baseline model controlled for any differences in geographic and climatic conditions that might have affected the choice of crops in certain regions. All of the data concerning the geographic and climatic controls were taken from the Geographically based Economic data (G-ECON) project. Similar to individualism/

[2] A historically acceptable term in 1922.



a b

Fig. 1. Shows a map of the suitability index of wheat, projected over the first-level administration districts (Fig. 1a), and a map of the suitability index of wheat, averaged over the first-level administration districts (Fig. 1b), in the United States. *Notes: GAEZ Suitability index of wheat is under rain-fed conditions, with low input levels, and using traditional management systems and cultivars. It is based on the average climatic conditions, between 1961 and 1990. The grid-level data is of cell size 5′ x 5' (approximately* 100 km^2*). Fig. 1 a reflects the grid data projected over the first-level administrative districts taken from the GADM. Fig. 1 b shows the actual distribution of the crop suitability of wheat, averaged across first-level administrative districts in the United States. The average is computed by dividing the total grid-level suitability, of each first level administrative district, by its total area.*

collectivism crops and the outcome variable, all the geographic and climatic controls were made over first-level administrative district boundaries that were available in GADM. These geographic and climatic controls were ecological factors that affected water supply and, effectively, determined whether a society cultivated one particular crop or not. The controls included landlockedness, mean elevation, distance to a river, historical precipitation and temperatures (averages between 1961 and 1990), and terrain roughness. Geographic and climatic conditions also affected the level of cooperation among societies; communities located in locations with arid climatic conditions and limited rainfall collaborated more. They had a strict inclination towards obedience, to ensure a cooperative management of the water systems and; thus were more likely to be collectivist societies. Conversely, farming communities in rugged, elevated areas with abundant rainfall required less cooperation among farming groups which, over time, led to more individualistic behavior.

Additionally, and over time, the cultivation of certain crops may have affected past economic outcomes; and thus influenced current technological preferences. Consequently, it was essential to control for historical development in order to isolate the cultural impact of crops that had contributed to past economic prosperity. Whereas data for historical development were unavailable at the subnational level, Henderson et al. (2018) had already demonstrated that physical geography accounted for 47% of any variation in economic activity. Therefore, since geographical advantages remained stable over time, it was reasonable to assume that the geographical characteristics, considered in this study, captured a significant proportion of past economic activity. For these reasons, it was vital that the study controlled for these geographic and climatic conditions, to demonstrate that individualism-/collectivism-enhancing crops were primary channel that affected individual attitudes towards technology.

3.3. Strength of crop measures

Given that the central premise of this paper is that cultural formations are a result of long-term exposure to certain crop production, the study also needed to make some sanity checks. These were made to test whether crop measures, which had been computed in the study, accurately resembled individualistic and collectivist cultures. Therefore, I computed an index for individualism, using questions from the WVS, and then compared it to the crop measures, created in the study. The question selection was informed by the work of Beugelsdijk et al. (2015), Schwartz (1990), and Ang (2019). Questions that characterized individualistic behavior were, (1) Nature of the work is independent; (2) Ownership of business is private; (3) Being hardworking is an important childhood quality; (4) Gender equality is important in politics, and (5) Respect for authority (recoded).

Columns (1)–(5) of Table 2 show the regressed crop measures against each WVS question. Column (6) uses the first principal component as a single measure of individualism. The models included individual and geographical controls at a regional level. The estimates also included country-fixed and year-fixed effects. In addition, I used several other alternative scores, to test the strength of individualism- and collectivism-enhancing crop measurements, at the country level. First, I used the same variables from the WVS as Ang (2019) had used, to construct a score for individualism, which used the principal component method, at a country level. Other alternative individualism measurements included individualism scores from Suh et al. (1998), Hofstede et al. (2010), and Tang and Koveos (2008) (See Appendix A, Table 6A for the regression estimates at the country level.). Overall, the results confirmed that the study's crop measurements captured individualism- and collectivism-enhancing environments well.

4. Findings

4.1. Subnational estimates - baseline results

Table 3 shows the ordinary least square estimates of the relationship between individualism/collectivism crop measures and individual attitudes towards technology at the subnational level. Columns (1) to (7) show the impacts of individualism- and collectivism-enhancing crops, on each individual question related to science and technology, conditioned on a series of covariates. Most coefficients appear significant with intended signs. Thus, it is clear that individualism-enhancing crops generated positive attitudes towards technology, whereas collectivism-enhancing crops had a negative effect. Column (8) shows the first principal component, of the seven questions, as dependent variable. The results also hold for the single index on attitude towards technology.

Table 2
Validation IDV/COLL crop measures using WVS data.

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. variable	Nature of work (independent)	Ownership of business	Child quality (hard working)	Women in politics	Resp. authority (recoded)	PCA
IDV crops	0.031**	0.075***	0.062***	0.023*	0.012	0.032***
	(2.296)	(5.579)	(5.175)	(1.792)	(1.029)	(2.608)
COLL crops	−0.045***	−0.108***	−0.071***	−0.024*	−0.023*	-0.047***
	(-3.261)	(-7.462)	(-5.445)	(-1.777)	(-1.672)	(-3.582)
Ind. controls	Yes	Yes	Yes	Yes	Yes	Yes
Geo. controls	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.193	0.074	0.243	0.239	0.172	0.304
No of obs.	51,452	51,452	51,452	49,003	48,897	47,087

Note: The dependent variable was based on the individual responses from the World Value Survey between 2010 and 2014. All individual responses and crop measures were at the first administrative district level. t statistics are in parentheses. The individual control variables were, age square, marital status and gender. Geographical controls were at the subnational level and include landlockedness, elevation, distance to river, precipitation (1961–1990), temperature (1961–1990) and terrain roughness. The baseline model controls were for country-fixed effects, as well as for year-fixed effects. The coefficients are standardized beta coefficients. Standard errors are robust and coefficients are significant at * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3
Effect of individualism and collectivism enhancing crops on attitudes towards S&T.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. variable	Q1	Q2	Q3	Q4	Q5	Q6	Q7	PCA
IDV crops	0.024*	0.044***	0.040***	0.001	0.025*	0.046***	0.066***	0.053***
	(1.651)	(2.984)	(2.707)	(0.055)	(1.794)	(3.218)	(4.605)	(3.735)
COLL crops	−0.040***	−0.008	−0.011	−0.020	−0.059***	−0.059***	−0.046***	−0.035**
	(-2.592)	(-0.496)	(-0.682)	(-1.324)	(-3.934)	(-3.899)	(-2.978)	(-2.329)
Age	−0.046*	−0.167***	−0.160***	−0.124***	0.078***	0.095***	0.035	−0.162***
	(-1.673)	(-5.969)	(-5.715)	(-4.507)	(2.885)	(3.403)	(1.249)	(-5.908)
Age squared	−0.027	0.140***	(0.144***	0.096***	−0.108***	−0.104***	−0.030	0.123***
	(-1.011)	(5.107)	(5.251)	(3.548)	(-4.028)	(-3.802)	(-1.115)	(4.556)
Marital status	−0.015***	0.019***	0.020***	0.014***	−0.003	−0.002	0.017***	0.020***
	(-2.851)	(3.434)	(3.657)	(2.663)	(-0.564)	(-0.312)	(3.132)	(3.791)
Gender, male	0.021***	0.043***	0.021***	0.031***	0.013***	0.022***	0.036***	0.047***
	(4.383)	(9.093)	(4.376)	(6.632)	(2.766)	(4.638)	(7.679)	(10.157)
landlockedness	0.232***	0.074***	0.213***	0.016	−0.042**	0.106***	0.342***	0.211***
	(11.117)	(3.697)	(11.082)	(0.765)	(-2.229)	(5.372)	(16.699)	(10.994)
Elevation	−0.026***	−0.028***	−0.028***	0.021***	0.009	−0.030***	−0.006	−0.022***
	(-3.524)	(-3.997)	(-4.044)	(2.864)	(1.198)	(-3.891)	(-0.807)	(-3.395)
Distance to river	0.048***	0.005	0.003	−0.039***	0.002	0.029***	0.001	0.000
	(5.864)	(0.552)	(0.381)	(-4.461)	(0.298)	(3.432)	(0.110)	(0.029)
Historical precipitation	0.040***	−0.027**	−0.031***	−0.010	−0.002	−0.037***	−0.052***	−0.032***
	(3.850)	(-2.534)	(-2.825)	(-0.927)	(-0.151)	(-3.659)	(-4.855)	(-3.113)
Historical temperature	0.010	0.070***	0.065***	0.044***	−0.061***	−0.017	0.150***	0.087***
	(0.703)	(4.609)	(4.287)	(3.068)	(-4.292)	(-1.199)	(9.980)	(6.006)
Terrain roughness	0.013	0.036***	0.046***	0.030***	0.031***	0.007	−0.035***	0.043***
	(1.558)	(4.503)	(5.580)	(3.948)	(3.909)	(0.895)	(-4.241)	(5.557)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.096	0.080	0.084	0.095	0.123	0.085	0.087	0.126
No of observations	41,045	41,045	41,045	41,045	41,045	41,045	41,045	41,045

Note: See Appendix A, Table 2A for the definitions of questions Q1-Q7 from the WVS. The dependent variable was the first principal component constructed, using questions Q1 to Q7. For the independent variables, the study used the unweighted average suitability index for individualism- and collectivism-enhancing crops. Both IDV and COLL crops were measured at the subnational level. The individual control variables were, age square, marital status and gender. The geographical controls were at the subnational level and included landlockedness, elevation, distance to river, precipitation (1961–1990), temperature (1961–1990) and terrain roughness. The World Value Survey data is from 2010 to 2014. The baseline model controls for country-fixed and year-fixed effects. The baseline sample consisted of 46 countries and 487 subnational regions. t statistics are in parentheses. The coefficients are standardized beta coefficients. Standard errors are robust and coefficients are significant at * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3 used standardized beta coefficients to facilitate interpretation, in terms of standard deviations. Hence, Column (8) implies that one standard deviation increase in individualism-enhancing crops, increases individual preference for technology by 0.053 standard deviations. Similarly, one standard deviation increase in collectivism-enhancing crops reduces individual preference for technology by 0.035 standard deviations. Overall, these results support the study's main proposition that science and technology are perceived as more favorable by societies that have historically cultivated individualism-enhancing (low labor-intensive) crops than they are by societies with a history of farming collectivism-enhancing crops.

4.2. Include additional historical and contemporary determinants

Table 4 shows the controls for a series of confounding factors, used to isolate the effect of historical farming's legacy on individual attitudes

Table 4
Effect of IDV and COLL crop measures on S&T attitudes after accounting for historical and contemporary effects.

	Control for Historical Effects											Control for Contemporary Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
IDV crops	0.118***	0.144***	0.067***	0.078***	0.122***	0.113***	0.125***	0.088***	0.139***	0.130***	0.127***	0.125***	0.060***	0.169***	0.070***
	(12.360)	(14.624)	(5.524)	(6.553)	(12.096)	(10.670)	(11.558)	(8.506)	(14.125)	(13.238)	(12.604)	(9.742)	(5.923)	(15.840)	(6.855)
COLL crops	−0.122***	−0.151***	−0.059***	−0.061***	−0.120***	−0.115***	−0.117***	−0.060***	−0.141***	−0.078***	−0.138***	−0.115***	−0.048***	−0.165***	−0.047***
	(-13.975)	(-16.511)	(-5.428)	(-5.752)	(-12.909)	(-12.262)	(-11.125)	(-5.840)	(-15.694)	(-7.997)	(-15.227)	(-10.253)	(-4.984)	(-16.463)	(-4.558)
Irrigation Potential 1900AD		−0.051***													
		(-8.609)													
Technology adoption 1500AD			0.270***												
			(17.941)												
(ln) population density 1500AD				0.035***											
				(2.714)											
Urbanization rate 1000BCE				0.020**											
				(2.373)											
Timing of Neolithic Revolution					0.108***										
					(8.702)										
Historical pathogens						−0.110***									
						(-11.288)									
French legal origin							0.060***								
							(7.441)								
German legal origin							0.182***								
							(21.821)								
Scandinavian Legal origin							0.036***								
							(6.988)								
Catholic 1900								−0.053***							
								(-3.498)							
Protestant 1900								0.041***							
								(4.064)							
Muslim 1900								0.157***							
								(18.894)							
Genetic diversity (predicted)									−0.023						
									(-0.950)						
Caloric yield (ancient, pre 1500)										−0.121***					
										(-14.943)					
Animal plow cultivation (ethno.)											0.051***				
											(5.786)				
Technology adoption 2000												0.203***			
												(16.000)			
Political development													−0.189***		
													(-27.917)		
Night light intensity														−0.070***	
														(-7.840)	
Irrigation potential															0.186***
															(23.595)
Actual irrigation															0.174***
															(14.852)

(*continued on next page*)

Table 4 (*continued*)

	Control for Historical Effects											Control for Contemporary Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Area equipped for irrigation															−0.205*** (-19.900)
Indi. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geo. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.057	0.063	0.075	0.061	0.061	0.066	0.071	0.069	0.059	0.065	0.060	0.059	0.076	0.071	0.090
No of observations	41,045	39,358	30,957	39,649	40,246	37,745	40,246	40,246	40,246	40,246	39,975	29,538	39,975	37,034	37,108

Note: The dependent variable is the first principal component constructed using questions Q1 to Q7. For IDV and COLL crops, the study used unweighted averages of the suitability indices for individualism and collectivism enhancing crops. IDV and COLL crops measurements are at the subnational level. The World Value Survey data is from 2010 to 2014. The coefficients are standardized beta coefficients with t statistics in parentheses. Standard errors are robust and coefficients are significant at * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

towards S&T. Column (1) presents the baseline estimates for reference. First, I controlled for historical irrigation potential. Buggle (2020) found that collectivist cultural norms were widespread among societies that relied on irrigated farming. Thus, there was a potential risk of endogeneity bias in the collectivism-enhancing crop measurements. Additionally, societies that historically relied on irrigation systems might have had a greater preference for technology today; and, consequently, may be positively biased towards technology. Column (2) shows the results of the baseline model controlled for historical irrigation, measured by the percentage of area, equipped for irrigation, in the year 1900.

Although this paper demonstrates that the labor intensity of crop cultivation can predict individual preference for scientific progress, we cannot rule out the possibility that the results were driven by historical economic development. That is, the farming of certain crops may have positively affected past economic outcomes – e.g., historical adoption of technology, population density, and urbanization – that might influence present-day attitudes towards technology. To mitigate this, Column (3) controls for technology adoption rates in 1500AD and Column (4) controls for population density in 1500AD, from Acemoglu et al. (2002), and historical urbanization rates in 1000BCE, from Peregrine (2003).

Next, I controlled for the timing of the Neolithic Revolution. Talhelm et al. (2014) described how herding communities are more individualistic than farming societies. In order for communities to change, from animal husbandry to crop cultivation, a sufficient knowledge of the relevant technologies is required; e.g., deforestation, crop cultivation, irrigation, water management, and harvesting techniques. Hence, the timing of agricultural transition could confound historical technological adoption levels and, thus, affect individual affinity towards technology. Column (5) shows the regression estimates. Column (6) uses historical pathogen prevalence, to control for potential collectivist behavior among societies prone to high communicable diseases, and Column (7) controls for the legal origins of countries, as compiled by La Porta et al. (1998). Column (8) lists the percentage of religious adherents in 1900, from Barro and McCleary (2003). Column (9) controls for genetic diversity, because it is found to generate individualistic cultural norms (Ashraf and Galor, 2018).

When hypothesizing cultural traits by tracing them back to the labor requirements of crop cultivation, there is a risk that the results could be driven by actual crop productivity, rather than labor intensity in farming. To mitigate this risk, Column (10) controls for historical caloric yield, as provided by Galor and Özak (2016). Finally, Column (11) controls for animal husbandry. Overall, the results appear consistent, after controlling for various historical effects.

Next, I controlled for a series of contemporary conditions that may have affected modern-day attitudes towards technology. Column (12) controls for current technological adoption rates, whereas Column (13) includes a polity IV score as a measurement of current political development. Column (14) controls for night light intensity, as a measure of current economic development. Then, I controlled for current irrigation levels. Researchers have claimed that societies that are dependent on irrigated agriculture have strong collectivist cultural norms, because of the strong cooperation that is required for the joint construction and maintenance of irrigated systems (Talhelm et al., 2014). Buggle (2020) analyzed technological adoption rates, from pre-1500 to 2000AD, and found that irrigation agriculture contributed to global technological divergence in the twentieth century. Therefore, irrigation agriculture has the potential to confound our baseline results. Thus, Column (15) controls for current irrigation potential, actual irrigation, and area equipped for irrigation, from Bentzen et al. (2017). Overall, the study found no evidence that irrigation obscured the main findings. Throughout the study's specifications, individualism-enhancing crops had a positive effect on individual attitudes towards technology, whereas collectivism-enhancing crops had a converse effect.

Table 5
Robustness test with different combinations of individualism and collectivism enhancing crops.

Crop combination	(1)	(2)	(3)	(4)	(5)	(6)
IDV (crops: Wheat)	0.068***					
	(3.503)					
COLL (crops: Potatoes)	−0.047**					
	(-2.323)					
IDV (crops: Wheat, Barley)		0.057***				
		(3.132)				
COLL (crops: Potatoes, Beans)		−0.041**				
		(-2.194)				
IDV (crops: Wheat, Barley, Oats)			0.090***			
			(5.705)			
COLL (crops: Potatoes, Beans, Maize)			−0.066***			
			(-4.386)			
IDV (crops: Wheat, Barley, Oats, Rye)				0.089***		
				(6.337)		
COLL (crops: Potatoes, Beans, Maize, Rice)				−0.063***		
				(-4.661)		
IDV (crops: Wheat, Barley, Oats, Rye, Flax)					0.095***	
					(5.738)	
COLL (crops: Potatoes, Beans, Maize, Rice, Sugar beet)					−0.064***	
					(-4.037)	
IDV (crops: Wheat, Barley, Oats, Rye, Flax, Sorghum)						0.102***
						(5.747)
COLL (crops: Potatoes, Beans, Maize, Rice, Sugar beet, Cotton)						−0.076***
						(-4.286)
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.127	0.132	0.132	0.132	0.132	0.132
No of observations	40,942	47,848	47,848	47,848	47,848	47,848

Note: Column (1) shows the results of the study's analysis f the impact of wheat *and potatoes on individual attitudes. Columns (2) to (4) add barley, oats, and rye, sequentially, to wheat, based on the decreasing intensity of the individualism. Similarly, beans, maize, and rice were added to potatoes in the decreasing intensity of collectivism. Columns (5) to (6) added additional crops, such as sorghum and flax to the baseline individualism crops, and cotton and sugar beet were added to the baseline collectivism crops. t statistics are in parentheses. The coefficients are standardized beta coefficients. Standard errors are robust and coefficients are significant at * $p < 0.10$, **$p < 0.05$, ***$p < 0.01$.*

4.3. Different combinations of crops

One major concern was whether the results are sensitive to the crops selected in the study. To address this issue, I examined the results' consistency under various combinations of baseline crops. I used historical labor intensities from the Department of Agriculture, U.S. (1922) to group the crops systematically. Wheat was the most individualistic crop and had the lowest labor intensity, at 10.3 labor hours. This was followed by barley (12.3), oats (13.1), and rye (17.1). Conversely, white potatoes were the most collectivist crop with the highest labor intensity, at 78.8 labor hours per acre, followed by beans (35.5), maize (33.0), and wetland rice.[3] Next, I regressed the most individualistic crop (wheat) against the most collectivist crop (potatoes) on individual attitudes towards technology. Column (1), in Table 5, displays the regression estimates. Column (2) shows the results when the next-most individualistic crop (barley) and next-most collectivist crop (beans) were added to the crops in Column (1) and the average crop measures for individualism/collectivism-enhancing crops were computed. Lastly, oats and rye were added, sequentially, to the individualism-enhancing crops, and maize and wetland rice were added to the collectivism-enhancing crops. Columns (3) and (4) show the results. The results, shown in columns (1) to (4), confirm that no particular group of crops was responsible for the results.

Next, I expanded the variety of crops, by including flax and sorghum (to the low labor-intensive crops) and added sugar beet and cotton (to the high labor-intensive crops) based on their historical labor intensities. I then added flax and sorghum, sequentially, to the baseline individualistic crops, and sugar beet and cotton to baseline collectivism crops. The results, shown in Columns (5) and (6), confirm the consistency of the results under an expanded variety of crops. Overall, the results support the concept that the types of crop, selected in the study, do not drive the positive effect of individualistic crops, and the negative effect of collectivist crops, on individual attitudes towards S&T.

5. Examining the underlying channels

5.1. Cultural transmission – evidence from Australia

Similar to Alesina et al. (2013), I went on to investigate parental transmission of culture, as a causal underlying mechanism of the results. Although this study assumes that the origins of individual perceptions of technology are agricultural, there exists a risk that they might partially be due to favorable institutions, markets, policies, and rules, as well as regulations that were conducive to innovation production. The study was able to keep the external environment constant, in order to analyze the impact of parental cultural transmission on attitudes towards technology, by restricting its sample to second-generation immigrants only. Data that is related to individual attitudes towards S&T, with additional information on parental ancestry, was only available for Australia, in the WVS. Consequently, this investigation was restricted to the children of migrants in Australia. Nevertheless, Australia's high immigrant population offers a natural advantage for testing cultural transmission.

Given this background, I determined an individual's ancestry by (one of) their parent's country of origin and considered only those whose parents were born outside of Australia. Individualism- and collectivism-enhancing crop measures were linked to the parent's ancestry. The regression models controlled for individual characteristics, such as age, gender, and marital status. As the crop measures were tied to the parent's

[3] The Department of Agriculture, U.S. (1922) does not report labor intensity for wetland rice. Since Talhelm et al. (2014) found the labor intensity of rice to be twice that of wheat, this study assumes the labor intensity of wetland rice to be approximately 20–30 labor hours per acre.

Table 6
Evidence from migrant children in Australia.

Panel A: Father's country								
Dep. variable	(1) Q1	(2) Q2	(3) Q3	(4) Q4	(5) Q5	(6) Q6	(7) Q7	(8) PCA
IDV crops (father's country of origin)	0.228***	0.106**	0.050	0.086**	−0.057*	0.055	0.231***	0.873**
	(6.979)	(3.195)	(1.284)	(2.681)	(-2.037)	(1.427)	(4.272)	(3.438)
COLL crops (father's country of origin)	−0.351***	−0.162**	−0.079	−0.139**	0.077	−0.082	−0.335***	−1.358**
	(-7.213)	(-3.289)	(-1.342)	(-2.843)	(1.837)	(-1.423)	(-4.105)	(-3.548)
Ind. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geo. Controls (father's country of origin)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE (father's country of origin)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.230	0.245	0.243	0.251	0.270	0.257	0.211	0.295
No of observations	213	213	213	213	213	213	213	213
Panel B: Mother's country								
Dep. variable	(1) Q1	(2) Q2	(3) Q3	(4) Q4	(5) Q5	(6) Q6	(7) Q7	(8) PCA
IDV crops (mother's country of origin)	0.048***	0.007	−0.003	0.034**	0.030	0.096**	0.077**	0.339**
	(4.578)	(1.111)	(-0.215)	(2.733)	(1.723)	(3.456)	(3.912)	(3.383)
COLL crops (mother's country of origin)	−0.112***	−0.014	0.004	−0.052**	−0.057*	−0.148**	−0.130***	−0.580***
	(-6.657)	(-1.306)	(0.234)	(-3.017)	(-2.039)	(-3.596)	(-4.310)	(-4.292)
Ind. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geo. Controls (mother's country of origin)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE (mother's country of origin)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.219	0.248	0.241	0.222	0.282	0.248	0.256	0.258
No of observations	190	190	190	190	190	190	190	190

Note: See Appendix A, Table 2A for the definitions of questions, Q1-Q7, from the WVS. The dependent variable in Column (8) was the first principal component of the seven questions. IDV and COLL crop measures were based on the parent's ancestry. Both IDV and COLL crops were measured at the regional level within Australia. Individual control variables are, age square, marital status and gender. Geographical controls were based on the parent's ancestry, and included landlockedness, elevation, precipitation (1961–1990), and temperature (1961–1990). The World Value Survey data was from 2010 to 2014. The baseline model controlled for regional fixed effects based on the host's region. The models also controlled for country-fixed effects based on the parent's ancestry. The baseline sample consisted of six administrative districts within Australia. The analysis was restricted to children, whose parents were born outside of Australia. t statistics are in parentheses. The coefficients are standardized beta coefficients. Standard errors are robust and coefficients are significant at * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7
Heterogeneous effects by gender and fertility rates.

	Heterogeneous effects by gender		
	(1)	(2)	(3)
	Male	Female	Difference in coefficients
IDV crops	0.0043***	0.0020*	115%
	(3.8290)	(1.9027)	
COLL crops	−0.0059***	−0.0047***	25%
	(-4.2514)	(-3.4965)	
Ind. controls	Yes	Yes	
Geo. Controls	Yes	Yes	
Year FE	Yes	Yes	
Continent dummies	Yes	Yes	
R square	0.037	0.063	
No of observations	19,780	20,240	

Note: The dependent variable was the attitude towards science and technology measured by the first principal component of the WVS questions. The individual control variables were, age square, marital status and gender. Geographical controls included landlockedness, elevation, precipitation (1961–1990), and temperature (1961–1990). The baseline model controlled for year-fixed effects and continental dummies. t statistics are in parentheses. Coefficients are significant at * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

home country, the geographic variables were also taken from the parent's respective country of origin. The considered variables were landlockedness, mean elevation, historical precipitation, and historical mean temperature. As this was a within-country analysis, I used regionally fixed effects to account for heterogeneities at the regional level, within Australia. In addition, I also controlled for country-fixed effects based on the parent's ancestry.

Panel A of Table 6 displays the estimates when ancestry is based on the father's country of origin, and Panel B reports those same results for the mother's country of origin. Accordingly, a majority of the coefficients are significant with the intended sign for both ancestries. Since cultural traits are transmitted across generations, it is reasonable to state that an ancestral legacy, of farming individualism-enhancing crops, had a positive effect on individual attitudes towards contemporary S&T. Conversely, an ancestral legacy of farming collectivism-enhancing crops led to a greater resistance to technology, across second-generation migrants in Australia.

5.2. Do gender norms matter

Next, I investigated whether gender disparity in farming practices triggered perceived differences in attitudes between men and women. To do this I tested whether heterogeneous differences might be observed between the attitudes of men and women, because of the various gender norms that were linked to crop cultivation. According to the World Bank's development indicators (WDI), in the year 2000, women's participation in agricultural production was approximately 64% in Sub-Saharan Africa, 74% in South Asia, and 44% in East Asia and the Pacific. Historically, these estimates would be expected to be significantly higher, given that female participation rates in agriculture have experienced an annual decline.[4] According to Talhelm et al. (2014), two of the most noteworthy differences between wheat and rice cultivation are the intensity of irrigation and the labor involved in the cultivation of these crops. Often, women take the central role in weeding, seed sowing, bird scaring, threshing, and drying the paddy harvest. Therefore, women's

[4] For example, in 1964, 95% of rural farmers in China were women (Huang, 1993).

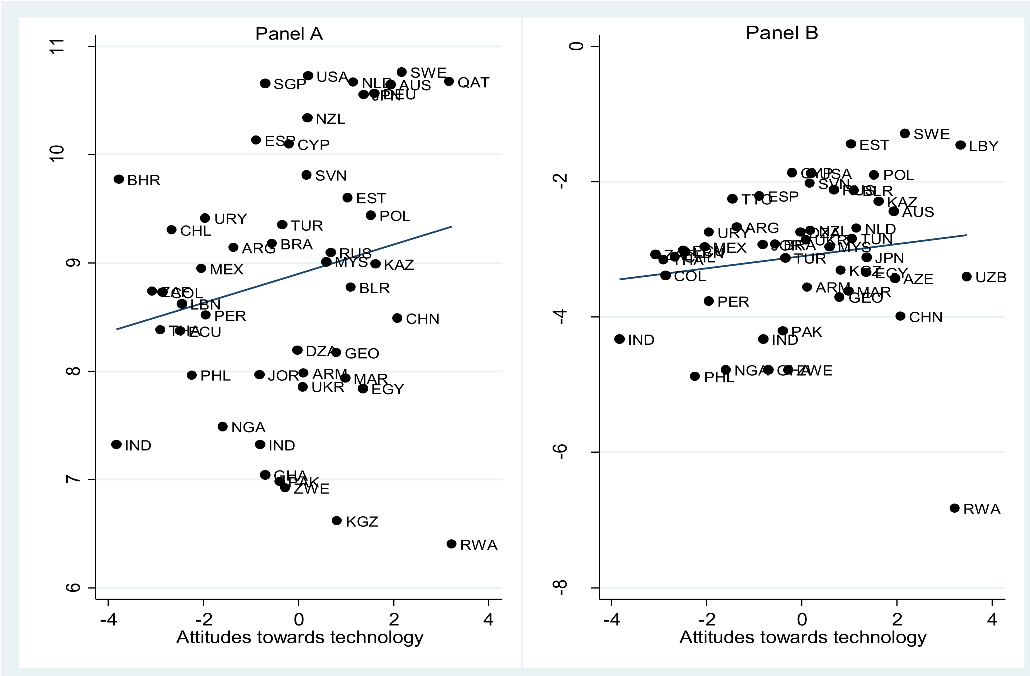


Fig. 2. Relationship between attitudes towards technology and economic development, measured by income per capita in 2015, and night light intensity per capita in 2010.

Table 8
Effect of S&T attitudes on innovation and technology diffusion.

	(1)	(2)	(3)
	Resident patent applications per million population 2015	Research and development expenditure (% of GDP in 2015)	High-technology exports (% of manufactured exports in 2015)
Attitudes towards S&T	0.280*	0.297*	0.304**
	(1.713)	(1.822)	(2.462)
Landlockedness	−0.120	−0.284**	−0.174
	(-1.359)	(-2.601)	(-1.388)
Mean elevation	−0.116	−0.099	0.235
	(-0.752)	(-0.577)	(1.219)
Distance to river	0.118	0.087	0.104
	(0.854)	(0.713)	(0.725)
Current precipitation	0.220	0.283	0.426**
	(1.419)	(1.440)	(2.060)
Current temperature	−0.283**	−0.437***	−0.477***
	(-2.089)	(-2.953)	(-3.421)
Terrain roughness	−0.092	−0.226	−0.321**
	(-0.908)	(-1.351)	(-2.485)
R square	0.254	0.430	0.307
No of observations	43	41	47

Note: The dependent variables were residents' patent applications, per million, in population, in 2015, R&D expenditure as a percentage of GDP in 2015, and high technology exports as a percentage of manufacturing exports in 2015. Data is from the WDI 2017. The independent variable was the first principal component of the seven attitudinal questions related to S&T. t statistics are in parentheses. The coefficients are standardized beta coefficients. Standard errors are robust and clustered at the country level. Coefficients are significant at * $p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

contribution to rice farming is considerably higher than it is in wheat farming. Hence, the collectivist cultural norms, which stem from labor-intensive crop production, should transmit to both men and women; who, thereafter, can be expected to show similar resistance to technology. Consequently, I expected the regression estimates of collectivism-enhancing crop measures to be similar for men and women.

On the contrary, women's contribution to low labor-intensive crop cultivation is significantly lower than that of men. Consequently, the transmission of cultural traits, stemming from labor intensity, should be significant for men, when compared to women. To test this, I separated the data by gender and estimated the effects separately. Columns (1) and (2) of Table 7 show the heterogeneous effects by gender. The coefficient difference, between males and females, is only 25% (statistically insignificant) for collectivism-enhancing crops.

It is clear that cultural transmission was similar, across genders, for labor-intensive crops. For individualism-enhancing crop cultivation, this difference was statistically insignificant. However, in terms of magnitude, the difference accounted for 115%. That is, the coefficient of IDV crops, in the men's sample, was twice that from the women's sample. Although inadequate, the evidence does indicate that cultural transmission was stronger for men, when compared to women, because of the low female participation in less labor-intensive crop production. However, the results for collectivist crops strongly supported the conjecture. Thus, there is reasonable evidence to support the concept that gender disparity in farming practices has influenced modern-day attitudes towards technology, among men and women. Although this researcher acknowledges that this method of comparing coefficients is relatively naïve and imperfect, it represents a modest effort, taken to identify the causal mechanisms that will need further investigation in the future.

6. *Additional findings - favorable attitudes and comparative development across societies*

Lastly, I examined the importance of positive attitudes towards technology on contemporary development across countries. It is reasonable to assume that countries with a strong preference for technology will innovate more and exhibit a higher adoption of technology; thereby, achieving a higher overall economic development. Thus, this section will demonstrate that favorable attitudes towards S&T are positively correlated with economic development. Fig. 2 shows the scatter plot of attitudes towards technology against income, in 2015, and night light intensity, in 2010, both per capita. As the scatterplots show, favorable attitudes were strongly correlated with higher economic development.

Next, I examined the impact of individual attitudes towards technology on innovation production. Table 8 shows the results of regression estimates, when the index of attitudes towards technology was regressed on innovation production. Columns (1) and (2) test the relationship between attitudes and innovation, by considering residents' patent applications and research and development (R&D) expenditure, respectively, as measures of innovation. Because exports of high technology could facilitate the technology diffusion process, Column (3) regress attitudes towards S&T against the percentage of high-technology exports in 2015. All of the regression estimates controlled for standard geographic controls. The study excluded country-fixed effects, to deal with the loss of degrees of freedom caused by the sample's small size. However, standard errors were robust and clustered at the country level. Overall, it is clear that favorable attitudes towards technology promote economic development, and technological innovation and diffusion.

7. Conclusions

It is widely acknowledged that deeply rooted cultural differences are an important determinant of contemporary economic performance. Similarly, agriculture has played a significant role in human civilization, throughout history. The transition from animal husbandry to crop cultivation led to diverse farming practices, each of which nurtured different socio-cultural values and beliefs. This paper's primary purpose was to investigate whether the antecedents of historical farming practices were linked to how individuals perceived modern-day technology. To do this, I hypothesized that cultural traits were formed by long-term exposure to diverse types of crop cultivation. Specifically, I explained that as labor-intensive crop production required interdependence, group conformity, and cohesion in farming communities, collective effort and strong interpersonal relationships were developed. These, in turn, maximized individual welfare and increased survival probability within those labor-intensive cropping farming environments. Equally, long-term exposure to such cooperative behavior has led to collectivist cultural norms within societies. However, communities that relied on low labor-intensive crops were more independent and, over time, they developed more individualistic cultural norms. Having established this backdrop, I tested the effects of the agricultural origins of individualistic and collectivist cultures on individual attitudes towards technology.

The study used attitudinal questions, about S&T from the WVS, and the crop suitability of eight major staple crops from the FAO as variants. It finds that positive attitudes, towards modern-day science and technology, emerge in societies with a history of farming low labor-intensive crops. Conversely, it finds that labor-intensive crop production had led to a lower acceptance of contemporary science and technology. These results appear consistent with a multitude of robustness tests.

Furthermore, this paper made a modest effort to identify the results' underlying channels. An analysis of Australian migrant data provided sufficient evidence to claim that crop labor intensity's effect, on attitudes towards technology, includes cultural elements that have been transmitted across generations. Likewise, gender disparity in farming practices has led to perceived differences, in those culturally transmitted attitudes, between men and women. Cultural transmission of attitude was noticeable, for men in low labor-intensive crop production, whereas it was found to be roughly similar among men and women in collectivism-enhancing environments. This stemmed from the high level of female participation in labor-intensive crop production.

This study also found attitudes towards technology were associated with higher economic development, and technological innovation and diffusion. Although differences in income or innovation production cannot be entirely explained by crop production, this study's findings offer reasonable evidence to support the idea that positive attitudes towards technology promote economic development.

Overall, this paper adds to the body of knowledge concerning critical technological differences across countries, based on an understanding of how individuals perceive technology from a cultural perspective.

Disclosure statement

The author declares that she has no relevant or material financial interests that relate to the research described in this paper.

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Declaration of competing interest

None.

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APPENDIX A

Table 1A
Definitions of variables and data sources

Variable	Description	Source
	[A] Key variables	
Attitudes towards technology	Six direct questions related to science & technology, and one question from Schwartz on creativity, hard work, and competition were selected from the WVS as a measure of individual attitudes towards technology. Taking the first principal component of the seven questions of the WVS, the study created an overall index on individual attitudes towards technology. The variable is constructed at the first administrative district level.	World Value Survey (Inglehart et al. (2014))
IDV crops	Grid-level crop suitability data is mapped to first administrative district level. The individualism enhancing crop measure is the unweighted average share of arable land suitability for the crops wheat, oats, rye, and barley, under rain-fed low input conditions. The crop suitability measures take variations in climate, soil, and terrain conditions into account.	FAO (GAEZ (2000))
COLL crops	Grid-level crop suitability data is mapped to the first administrative district level. The collectivism-enhancing crop measurement is the unweighted average crop suitability of maize, wetland rice, white potato, and beans under rain-fed low input conditions.	FAO (GAEZ (2000))
	[B] Baseline geographic control variables, (data available at the first administrative district level.)	
Landlockedness	A dummy variable that equals 1, if a country is fully surrounded by land, otherwise it is 0.	The G-ECON Project (G Econ (2008))
Latitude	The absolute value of the latitude of each first level administrative district.	The G-ECON Project (G Econ (2008))
Distance to nearest river	The mean distance a first-level administrative district is from the nearest sea-navigable river (in km).	The G-ECON Project (G Econ (2008))
Mean precipitation	The average, annual precipitation in a first-level administrative district, for the period 1961–1990 (in mm).	FAO (GAEZ (2000))
Elevation	The mean elevation of a first-level administrative district for a country that is above sea level (in km).	The G-ECON Project (G Econ (2008))
Terrain ruggedness	An index that measures small-scale terrain irregularities in each first-level administrative district of country.	The G-ECON Project (G Econ (2008))
Mean temperature	The average annual temperature of a first-level administrative district of a country over the period 1961–1990 (in Celsius).	FAO (GAEZ (2000))
	[C] Baseline individual control variable (data available at the individual level.)	
Age	Age is a discrete continuous variable that indicates an individual's age at the time of the survey. The age-squared measurement is computed by taking the square of age.	World Value Survey (Inglehart et al. (2014))
Gender	A dummy variable that takes the value 1 if the individual is male or 0, otherwise.	World Value Survey (Inglehart et al. (2014))
Marital Status	A dummy variable that takes the value 1 if the individual is married or 0, otherwise.	World Value Survey (Inglehart et al. (2014))
	[D] Historical indicators (data available at the country level.)	
Irrigation 1900	Share of land equipped for irrigation in 1900.	Bentzen et al. (2017)
Technology adoption in 1500 AD	The average adoption levels of technology in 1500 AD. The measure considers sectors, such as agriculture, transportation, communications, industry, and military.	Comin et al. (2010)
Neolithic Revolution	The number of years, since the transition from herding to sedentary agriculture, was estimated to have occurred (in thousand years).	Ashraf and Galor (2011)
Population density in 1500 AD	Natural log of the population in 1500 AD, divided by land area.	Acemoglu et al. (2001)
Urbanization index 1000BCE	This is the historical urbanization rate in 1000BCE constructed at the country-level.	Peregrine (2003)
Historical pathogen prevalence index	The pathogen prevalence considers the average prevalence ratings of the diseases leishmanias, schistosomes, trypanosomes, malaria, typhus, filariae, and dengue. The following coding system was used to estimate the disease prevalence: 0 if the disease was completely absent or not reported, 1 if reported rarely, 2 if reported occasionally or only moderately, and 3 if the disease was reported as severe or an epidemic, at least once. The estimates are standardized and unweighted average was used to form an index. A positive value represents higher disease prevalence.	Murray and Schaller (2010)
Legal origins	A dummy variable that identifies the legal traditions of a country as British, French, German, or Scandinavian.	La Porta et al. (2008)
Genetic diversity	An index of predicted genetic diversity.	Ashraf and Galor (2013)
Caloric yield	Ancestry-adjusted average caloric suitability for 53 crops (pre 1500).	Galor and Özak (2016)
Animal plow cultivation	Animal plow cultivation index, using ethnologue data.	Galor and Özak (2016)
	[D] Contemporary variables (data available at the country level.)	
Technology adoption 2000	The average adoption levels of technology in 2000 AD. The measurement considers sectors, such as agriculture, transportation, communications, industry, and military.	Comin et al. (2010)
Light intensity in 2010	Log-transformed night light intensity per capita in year 2010.	The G-ECON Project (G Econ (2008))
Political development	Institutional constraints on decision-making by chief executives. The data are from the Polity IV project.	Marshall et al. (2016)
Irrigation potential	The share of agriculture land suitable for irrigation (impact class 5).	Bentzen et al. (2017)
Actual irrigation	Percentage of actual irrigated land, from total cultivated.	Bentzen et al. (2017)
Area equipped for irrigation	Percentage of area equipped for irrigation, in the year 2000.	Bentzen et al. (2017)
Mean agriculture suitability	A measure of land suitability for agriculture, based on ecological, climate and soil conditions.	Bentzen et al. (2017)
	[E] Control variables for China (data available at the regional level).	
Population density	Population density was calculated using population (in 10,000 persons) and land area (sqkm) for 22 provinces within China.	NBSC (2020)

(continued on next column)

Table 1A (*continued*)

Variable	Description	Source
	[A] Key variables	
Income per capita	Per capita regional income (yuan/person).	NBSC (2020)
Irrigation	The total irrigated land, in 2012, at the provincial level.	NBSC (2020)
Education-primary	Students per 100,000 populations, in primary education.	NBSC (2020)
Education-secondary	Students per 100,000 populations, in secondary education.	NBSC (2020)
Gini coefficient	Gini coefficient in 2012.	NBSC (2020)
Disease (1408–1911)	The sum of historical diseases within a province, for the period 1408–1911, and include communicable diseases, such as smallpox, cholera, epidemic hemorrhage, and the plague.	Zhu et al. (2019)

Table 2A
Questions related to science and technology, available in different waves of the WVS and the correlation between PC1 and the dependent variable.

	2005–2009	2010–2014	2005–2014	PC1 (2010–2014)
Q1: Science is important in daily life		×		0.3021
Q2: S&T makes our lives better	×	×	×	0.8339
Q3: S&T gives more opportunities to the next generation	×	×	×	0.8248
Q4: The world is better off with S&T	×	×	×	0.6728
Q5: The world depends too much on S&T (recoded)	×	×	×	0.1189
Q6: Science does not break people's ideas about right and wrong		×		0.1762
Q7: Competition is good as it stimulates people to work hard and develop new ideas		×	×	0.2980

Table 3A
Descriptive Statistics

Variable	Observations	Mean	Std. dev	Minimum	Maximum
Tech. Attitude (Dep. Variable)	49,611	3.14	1.43	−6.02	2.51
IDV crops	41,262	28.85	17.95	0.07	87.34
COLL crops	41,262	22.38	12.73	0.25	78.46
Age	49,545	40.37	15.76	16	99
Mean elevation	1108	150.52	173.97	0	895.74
Distance to river	1108	441022.9	469345.5	0	2,564,713
Mean precipitation	3320	1119.79	739.05	1	4530
Mean temperature	3320	18.01	8.37	−23.38	29.97
Terrain roughness	1108	0.17	0.21	0	1.13

Table 4A
Summary Statistics of crops suitability indices

Crop	Mean suitability index	Minimum suitability index	Maximum suitability index
Wheat	31.33	0.02	99.91
Barley	30.02	0.02	99.91
Oats	36.45	0.07	99.91

(*continued on next column*)

Table 4A (*continued*)

Crop	Mean suitability index	Minimum suitability index	Maximum suitability index
Rye	35.90	0.07	99.91
Potato	22.18	0.02	80.73
Beans	26.37	0.1	94.52
Maize	26.44	0.03	91.94
Rice	13.98	0.01	63.00

Table 5A
Summary of labor intensities of crops from various sources

Crop	Lenhart (1945)	U.S. Department of Agriculture (1922)	Cooper et al. (1916)	Pimentel (2009) (developing countries)	Pimentel (2009) (developed countries)	Fouka and Schlaepfer (2017)
	Man-weeks of labor per acre	Total man-labor hours	Labor hours per acre	Labor hours per hectare	Labor hours per hectare	Labor share
Peas	3.0413					0.299
Sugar beets	2.0857	113.7				
Cotton	1.7596	114.7				
Potatoes	0.9888	78.8	44.4		35	0.571
Hay, Alfalfa	0.3694					
Sorghum	0.0500					
Flax	0.0454		13.7			
Grain, small	0.0256					
Apples		391.3			400	
Tobacco		277.4				
Field beans		35.0				0.601
Corn		33.0	26.2	634	11.4	
Kafir and milo		19.8				
Alfalfa		17.8				
Rye		17.1	10.3			0.149
Spring wheat		16.8				
Oats		13.1	13.5			0.370
Barley		12.3	12.8			0.079
Wild and grain Hay		11.4	12.2			
Clover Hay		10.4				
Wheat		10.3	12.3	684	7.8	0.400
Winter wheat		9.7				
Mixed tame Hay		8.5				
Timothy Hay		8.1				
Clover seed		7.2	9.2			
Timothy seed		6.6	5.1			
Mangels			180.7			
Corn silage			32.6			
Fodder Corn			30.4			
Millet			17.3			
Hemp			14.3			
Tame Hay			12.3			
Rice			1703		11	
Soybeans				744	6	
Cassava				1632		
Carrots	12.8198					
Plums	6.1250					
Onions	5.6111					
Broccoli	5.2222					
Squash	4.5000					
Onion seeds	4.3125					
Peaches	4.1931					
Tomatoes	4.1769				184	
Cabbage	3.8462					
Apricot	2.7667					
Asparagus	2.6667					
Grapes	2.5492					
Lettuce	2.3300					

(*continued on next column*)

Table 5A (*continued*)

Crop	Lenhart (1945)	U.S. Department of Agriculture (1922)	Cooper et al. (1916)	Pimentel (2009) (developing countries)	Pimentel (2009) (developed countries)	Fouka and Schlaepfer (2017)
	Man-weeks of labor per acre	Total man-labor hours	Labor hours per acre	Labor hours per hectare	Labor hours per hectare	Labor share
Watermelons	1.7143					
Grapes, wine	1.6500					
Grapes, raisins	1.1662					
Grapefruit	1.1447					
Oranges	1.1034				200	

Note: Column (1): The total acreage of harvested crops and man-weeks of labor are the sum of Imperial, Kern and Kings Counties in California. Column (2): The total pf man-labor hours is the aggregate average of man-labor hours, per acre, at the national level. The 1922 report on crop data, pertaining to 1921, and those crops with a year in bracket refer to data in the corresponding year. Column (3): The data is from the Northfield, Marshall and Halstad Counties in Minnesota State, United States. The above labor hours per acre are based on the average of the three farms. Data on potatoes and mangels are from Glydon Clay experimental farm (1906–1907). The original data are taken from Cooper et al. (1916).

Table 6A
Strength of crop measures capturing individualism and collectivism cultures at the country level

	(1)	(2)	(3)	(4)
	Ang (2019)	Suh et al. (1998)	Hofstede et al. (2010)	Tang and Koveos (2008)
IDV crops	0.766***	0.790**	0.539**	0.766***
	(2.948)	(2.298)	(2.454)	(2.948)
COLL crops	−0.511**	−0.524*	−0.123	−0.511**
	(-2.131)	(-1.958)	(-0.630)	(-2.131)
Landlocked	−0.048	0.073	0.074	−0.048
	(-0.408)	(0.412)	(0.759)	(-0.408)
Mean elevation	−0.283*	0.105	−0.062	−0.283*
	(-1.959)	(0.481)	(-0.453)	(-1.959)
Terrain roughness	−0.158	−0.264*	−0.087	−0.158
	(-1.318)	(-1.723)	(-0.697)	(-1.318)
Historical precipitation	0.411**	0.028	−0.040	0.411**
	(2.225)	(0.159)	(-0.272)	(2.225)
Clustering (country level)	Yes	Yes	Yes	Yes
R square	0.377	0.326	0.280	0.377
No of observations	58	45	66	58

Note: Individualism index in Column (1) is based on the questions used by Ang (2019). They are, (1) Independence is an important childhood quality, (2) imagination is an important childhood quality, (3) obedience as an important childhood quality, (4) do not live with parents, (5) divorce is justifiable, and (6) business ownership is private. Column (2)–(4) used individualism scores developed by Suh et al. (1998), Hofstede et al. (2010) and, Tang and Koveos (2008) as the dependent variable. Unlike in the baseline model, country-fixed effects are excluded, in order to deal with the loss of degrees of freedom caused by the small sample size. Instead, standard errors are clustered at the country level to control for heterogeneous effects at the country level.t statistics are in parentheses. The coefficients are standardized beta coefficients. Standard errors are robust and coefficients are significant at * $p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

APPENDIX B

1. *Evidence from China*

This section provides evidence to complement Talhelm et al. (2014) findings, using provincial data from China. Conducting a within-country comparison using China has several advantages. Despite being a collectivist society, China is technologically advanced and one of the fastest-growing global economies. Given China's current technological and economic sophistication, it is an important exemplar, in our efforts to understand whether historical farming legacy can explain variations in modern-day attitudes towards technology. In addition to being a collectivist culture, China is more ethnically and politically homogeneous than the United States, Europe, or other Sub-Saharan countries (Talhelm et al., 2018). Thus, it makes a suitable control for a wide range of institutional and cultural (i.e. linguistic and religious) heterogeneities that might otherwise confound results.

Furthermore, China traditionally grows both labor-intensive and non-labor intensive crops. For example, northern China produces mainly wheat, while southern China grows rice. The fact that China has distinct geological and climatic conditions, which are favorable for labor-intensive (rice) and non-labor intensive (wheat) crop production, makes it a natural testbed to test this study's hypotheses. I expect the findings to complement Talhelm et al. (2014) work on the *rice theory of culture*. Figures 1 and 2, in Appendix B, show the distribution of individualism/collectivism-enhancing crop measures across 31 provinces in China. Table 1B provides regression estimates for a within-country comparison of China. The estimates in Column (1) control for age, gender, and marital status. Similar to previous analyses, Column (2) controls for historical precipitation, historical temperature, mean elevation, and landlockedness in order to consider the geographical and climatic differences across provinces.

Once I had those measurements, I ran a series of robust checks to validate the estimates. First, I controlled for cotton suitability. Activities, such as sowing, harvesting, double cropping, and plant pruning involve a large amount of labor. As China is also one of the world's leading cotton-producing countries, the cultivation of cotton may also have influenced nurturing collectivist cultural norms. Therefore, Column (3) controlled for cotton suitability across China. Column (4) controlled for population density. Because China is one of the most populated countries in the world, I controlled for any possible endogeneity bias that may have arisen from a high-population density (Vandello and Cohen, 1999). Next, I accounted for the modernization hypothesis by controlling for regional income per capita, the results of which are shown in Column (5). Column (6) shows the results controlled for irrigated land. Column (7) controlled for historical diseases. According to Fincher et al. (2008), parasite-stress theory, and a high prevalence of communicable diseases prevented societies from interacting with outsiders, thus creating collectivist cultural norms. Consequently, I controlled for historical diseases, using the data formulated by Zhu et al. (2019). Columns (8) and (9) controlled for income inequality and education across provinces. Lastly, Column (10) tested the joint effect of all variables. Overall, the results are consistent, and suggest that the historical production of low-labor-intensive crops leads to a positive affinity towards science and technology. Conversely, greater resistance to technology is shown by societies that historically farmed labor-intensive crops, within China.

2. *Country level estimates*

In addition to the subnational estimates, I tested the consistency of the study's results at the cross-country level. Table 2B shows the robustness of the results, when individualism/collectivism-enhancing crop measurements and geographic controls are aggregated to the country level instead of the subnational level. The study aggregated individual responses to the country level, and used clustered standard errors to account for country-specific heterogeneity. Country-fixed effects were excluded, in order to deal with the loss of degrees of freedom caused by the sample's small size. However, year-fixed effects were included. Column (1) shows the results of the baseline model at the country level. Next, I introduced a series of covariates, to control for historical conditions, such as irrigation, in 1900, the technology adoption rate, in 0AD, the urbanization rate, in 1500AD, population densities, in 1500AD, the timing of the Neolithic revolution, historical diseases, and legal origins. See Columns (2)–(7) for those results. I control for night light intensity, as a contemporary condition, in Column (8). Then, the study tested whether the results were strengthened, after controlling for migration. As migrant populations may alter the cultural values and norms of indigenous populations, it is important to account for net migration flows. The results are shown in Column (9). They confirm that migration flows did not change the effect of farming practices on modern-day attitudes towards technology. Lastly, Columns (10) and (11) controlled for current irrigation potential. Overall, the results hold even at the cross-country level.

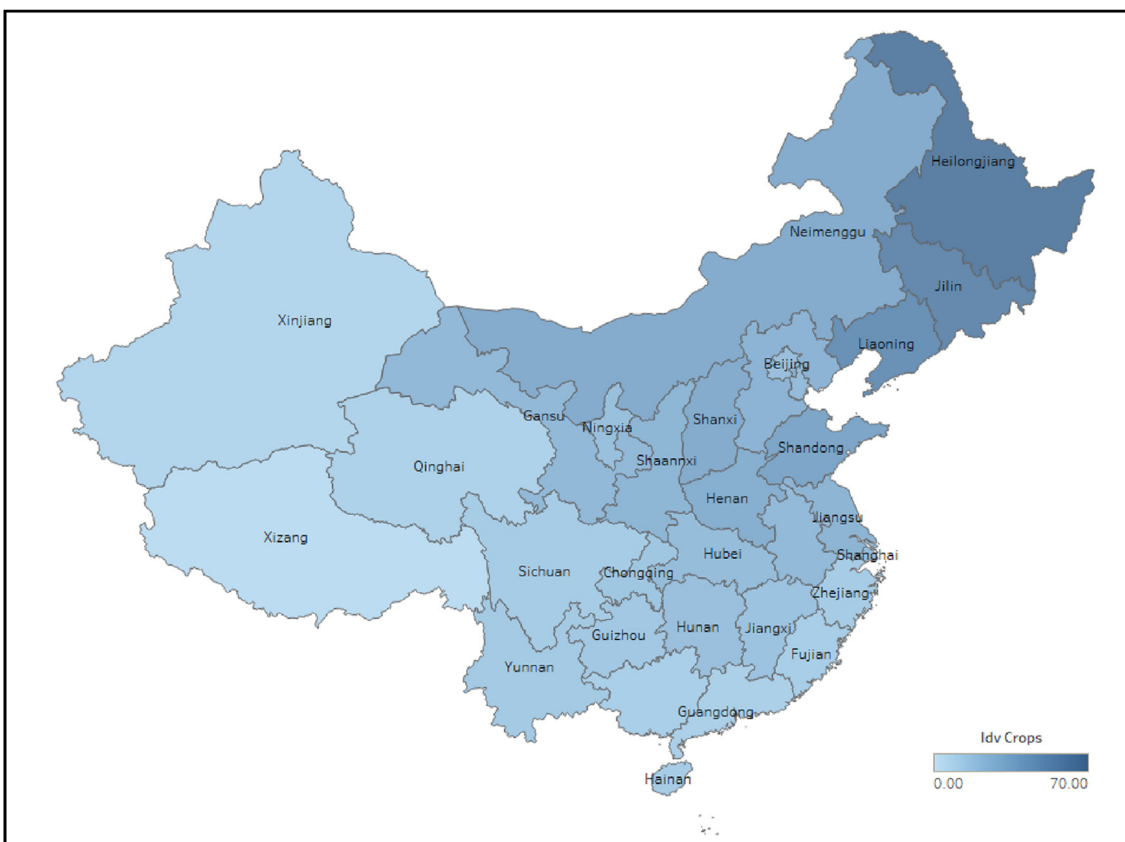

Fig. 1. Distribution of the individualism-enhancing crops across China

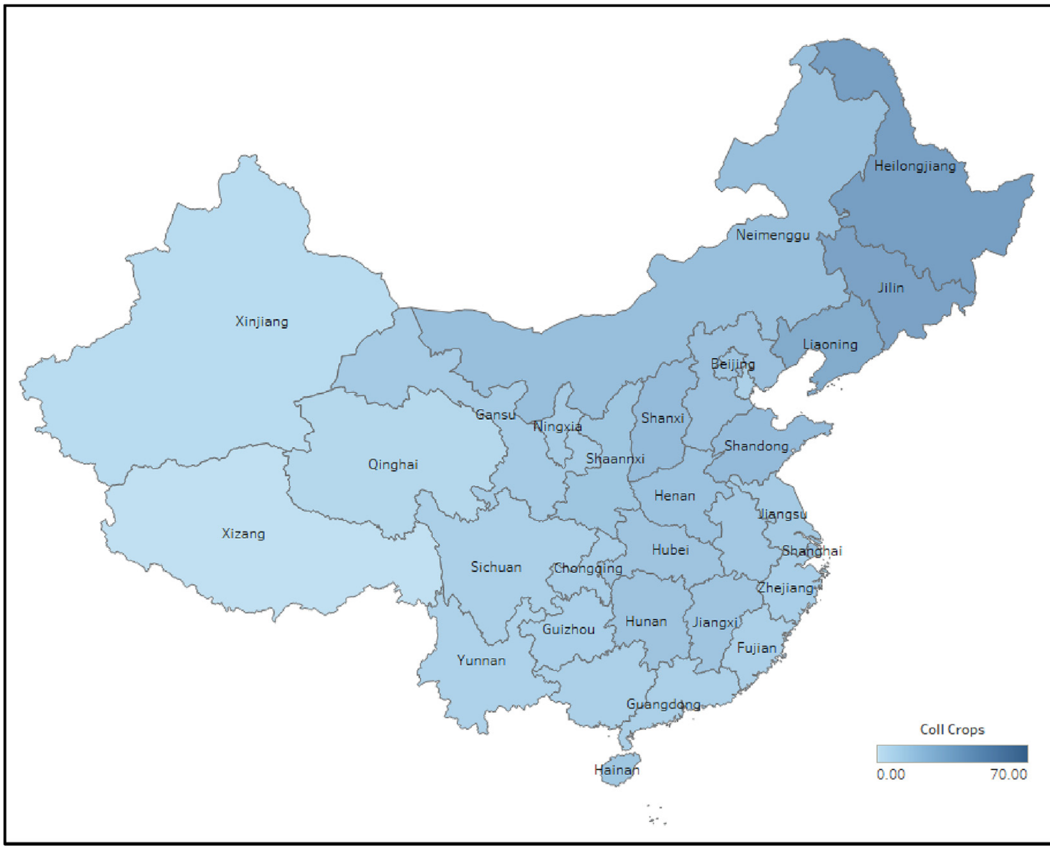

Fig. 2. Distribution of the collectivism-enhancing crops across China

Table 1B
OLS estimates for China

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
IDV crops	0.100***	0.266***	0.489***	0.263***	0.266***	0.265***	0.318***	0.286***	2.843***	3.948***
	(5.322)	(17.294)	(18.896)	(12.865)	(17.072)	(15.578)	(2.895)	(3.221)	(22.386)	(38.920)
COLL crops	−0.106***	−0.656***	−0.741***	−0.654***	−0.657***	−0.658***	−0.708***	−0.674***	−2.885***	−11.994***
	(-6.738)	(-27.157)	(-11.502)	(-23.845)	(-27.461)	(-27.430)	(-11.096)	(-8.606)	(-23.351)	(-34.672)
Cotton suitability			−0.056							14.500***
			(-1.265)							(33.488)
Population density				0.004						9.993***
				(0.227)						(34.450)
Income per capita					0.001					−11.251***
					(0.227)					(-34.964)
Irrigated Land						−0.006				−5.314***
						(-0.227)				(-32.059)
Disease (1408–1911)							0.019			−0.271***
							(0.486)			(-31.754)
Gini coefficient								0.004		1.387***
								(0.227)		(39.612)
Students in primary edu.									0.365***	−1.674***
									(17.560)	(-43.411)
Students in secondary edu.									−1.952***	−7.277***
									(-23.723)	(-35.709)
Indi. controls	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes
Geo. controls	No	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes
Regional FE	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes
R square	0.140	0.140	0.136	0.140	0.140	0.140	0.107	0.140	0.140	0.090
No of observations	1412	1412	1296	1412	1412	1412	1251	1412	1412	1135

Note: See Appendix A, Table 2A for the definitions of questions Q1-Q7 from the WVS. The dependent variable was the first principal component constructed using questions Q1 to Q7. The World Value Survey data is from 2010 to 2014. For independent variables, the study used the unweighted average suitability index for individualism- and collectivism-enhancing crops. Both IDV and COLL crops were measured at the subnational level. Individual control variables were age, age square, marital status and gender. Geographical controls were at the subnational level and included landlockedness, elevation, precipitation (1961–1990) and temperature (1961–1990). Column (7) and (8) included absolute latitude. The baseline model controlled for regional-fixed effects. The sample consisted of 22 provinces, within China, that included Hebei, Jiangsu, Shandong, Jilin, Guizhou, Hubei, Beijing, Sichuan, Shaanxi, Zhejiang, Chongqing, Guangxi, Heilongjiang, Hunan, Shanxi, Gansu, Guangdong, Qinghai, Henan, Anhui, Liaoning, and Jiangxi. t statistics are in parentheses. The coefficients are standardized beta coefficients. Standard errors are robust and clustered at the sub regional level. Coefficients are significant at * p < 0.10, **p < 0.05, ***p < 0.01.

Table 2B
Country level estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
IDV crops	0.496*	0.550**	0.529*	0.505*	0.514*	0.485*	0.545**	0.717**	0.516*	0.502*	0.461*
	(1.814)	(2.109)	(1.764)	(1.884)	(1.766)	(1.725)	(2.118)	(2.505)	(1.861)	(1.789)	(1.843)
COLL crops	−0.699***	−0.746***	−0.941***	−0.691***	−0.719***	−0.705***	−0.729***	−0.911***	−0.738***	−0.714***	−0.608**
	(-2.884)	(-3.056)	(-3.238)	(-2.831)	(-2.864)	(-2.817)	(-3.078)	(-3.467)	(-2.889)	(-2.909)	(-2.232)
Irri. potential 1900AD		0.127									
		(1.111)									
Tech adoption 0AD			−0.096								
			(-0.943)								
Urbanization 1500AD			0.168								
			(1.160)								
(ln) population density 1500AD				0.064							
				(0.481)							
Timing of Neolithic revolution					−0.029						
					(-0.181)						
Historical pathogens						0.136					
						(0.807)					
French legal origin							−0.180				
							(-1.182)				
German legal origin							0.258***				
							(3.630)				
Scandinavian Legal origin							0.099**				
							(2.415)				
Night light intensity								−0.249**			
								(-2.606)			
Net migration									0.022		
									(0.182)		
Area equipped for irrigation										−0.033	
										(-0.313)	
Actual irrigation											0.308**
											(2.502)
Geo. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster std. errors (country level)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.531	0.544	0.744	0.538	0.531	0.528	0.584	0.602	0.533	0.532	0.614
No of observations	48	47	35	47	48	46	48	44	47	48	42

Note: The dependent variable was the first principal component constructed using questions Q1 to Q7. The study used unweighted averages of the suitability indices for individualism and collectivism-enhancing crops. IDV and COLL crops measures were at the country level. Geographical controls were at the country level and included landlockedness, elevation, distance to river, historical precipitation and temperature (1961–1990), and terrain roughness. The World Value Survey data was from 2010 to 2014. The baseline sample contained 44 countries. t statistics are in parentheses. The coefficients are standardized beta coefficients. Standard errors are robust and clustered at the country level. Coefficients are significant at * p < 0.10, **p < 0.05, ***p < 0.01.

Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2020.10.012.

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