Essays on culture and innovations

Jayasekara Dinithi Nilanga

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**NANYANG
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**ESSAYS ON CULTURE AND
INNOVATIONS**

**JAYASEKARA DINITHI NILANGA
SCHOOL OF SOCIAL SCIENCES**

2021

ESSAYS ON CULTURE AND INNOVATIONS

JAYASEKARA DINITHI NILANGA

School of Social Sciences

A thesis submitted to the Nanyang Technological University in partial
fulfilment of requirement for the degree of
Doctor of Philosophy

2021

Statement of Originality

I certify that all work submitted for this thesis is my original work. I declare that no other person's work has been used without due acknowledgement. Except where it is clearly stated that I have used some of this material elsewhere, this work has not been presented by me for assessment in any other institution or University. I certify that the data collected for this project are authentic and the investigations were conducted in accordance with the ethics policies and integrity standards of Nanyang Technological University and that the research data are presented honestly and without prejudice.

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4 Jan 2021

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Date

James Ang

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Assoc. Prof. James Ang

Authorship Attribution Statement

This thesis contains

- materials from papers published in a peer-reviewed journal,
- papers accepted at conferences in which I am listed as an author.

Chapter 1 is published as Jayasekara, D.N. & Fredriksson, P.G. Culture, intellectual property rights, and technology adoption, *The Quarterly Review of Economics and Finance* 80, 317-330 (2021). DOI: 10.1016/j.qref.2021.03.007. It was presented as D.N. Jayasekara. “Culture, Intellectual Property Rights and Technology Adoption” at the 15th *International Conference of the Western Economic Association International* (Tokyo) in March 2019, *NTU-Chulalongkorn-Thammasat Trilateral Workshop in Economics* (Singapore) in October 2018, and *Singapore Economic Review Conference* (Singapore) in August 2019.

The contributions of the co-authors are as follows:

- I compile the dataset, design the regression framework to test the hypothesis, provide an analytical framework, review the literature, and discuss the results under Associate Professor James Ang's supervision.
- Professor P.G. Fredriksson polished the paper, improved the exposition of the materials, and assisted in providing guidance and strategies to get the paper accepted for publication.

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Chapter 3 was presented as D.N. Jayasekara & J.H.W. Tan. “Trusting Cultural Similarities When Sharing Knowledge: An Empirical and Experimental Approach” at the *NTU-Chulalongkorn-Thammasat Trilateral Workshop in Economics* (Virtual) in November 2020.

The contributions of the co-authors are as follows:

- Associate Professor Jonathan Tan supervised, directed, and funded the research.
- I co-designed the experiment with Assoc. Prof Tan. Organization of experiment, data collection, analyses, and manuscript writing were completed by me under Associate Professor Jonathan Tan's supervision.

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Executive Summary

Globally, technology innovation and adoption have become central to economic progress. However, the role of culture and its influence on technology innovation and adoption still remains a black box. The thesis comprises three independent essays to uncover the dynamics of culture and its link to technology innovation and adoption using empirical and experimental approaches. There is a consensus that individualism/collectivism is one of the most important cultural dimensions to explain technological, income and productivity differences. Hence, the first two essays employ individualism and collectivism to explain cross-country variations in technology adoption and preferences.

The literature argues that culture and institutions serve as complements or substitutes, depending on existing economic conditions. In the first chapter, we propose that deep-seated cultural differences and the strength of institutions jointly explain technology adoption behavior. We hypothesize that the adoption of novel technologies is more likely to occur in individualistic societies where risk-taking and the drive to be on the technology frontier is viewed as important. This behavior is reinforced by strong intellectual property rights (IPR), where the benefit of investments in new technology is likely to be fully internalized. Additionally, we hypothesize that strict IPR regimes are associated with more intense technology adoption, particularly in individualistic cultures, where individual behavior will take advantage of favorable institutions. Thus, we merge two hitherto separate strands of literature to bring further clarity to the ongoing debate on the effects of IPRs. Using cross-country analyses, we confirm that individualistic societies with strong IPR protection are more inclined to adopt new technologies and that they are mutually reinforcing.

Chapter 2 examines how agricultural legacies have a lasting effect on cultural formations and their implications on individual preferences for modern technology. Cultural traits are formed by long-term exposure to specific types of crop cultivation, and it can be traced to the labor requirements of crops. Using historical labor intensities of crop production, we find societies that 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. Second-generation migrant data reveals that parental transmission of culture is an important channel for cultural transmission. Heterogenous effects by genders show that cultural transmissions are similar across men and women for labor-intensive crops because female participation in labor-intensive crop production is proportionately higher than low labor-intensive crops where cultural transmissions were stronger for men due to low female participation in crop production.

Deviating from the first two chapters, chapter 3 utilizes empirical and experimental methodologies to explore the role of culture in promoting collaborative innovation, particularly individual-level behavioral mechanisms that drive such strategic decisions. Results from our empirical pre-study motivate the experimental approach. We test the cooperative commitment of individuals under different forms of generic frame-neutral cultural manipulation. In a controlled virtual lab, the cultural similarity between ingroup and outgroup members was modeled by *beliefs, fate, rituals, and experiences*. The experimental results show that knowledge sharing between ingroup members is higher than with outgroup members due to trust in cultural similarity. Additionally, cultural similarity increases its comparative advantage in the presence of weak IPR protection. Prosocial behavior is found to mediate the positive effects of cultural similarity on knowledge sharing decisions.

1. Culture, Intellectual Property Rights, and Technology Adoption

1.1. Introduction

Comin and Mestieri (2018) argue that a widening gap in the intensity of individual technology adoption accounts for 75% of the increase in income divergence. Understanding the drivers of technology adoption is thus of high importance (see also Comin et al., 2008; Comin et al., 2010; Comin and Hobijn, 2010). What explains differences in technology adoption across countries? This paper seeks to shed novel light on this question by considering both intellectual property rights protection and the cultural dimension of individualism versus collectivism.

There is an ongoing debate in this literature on whether stricter IPR protection regimes may hamper, expand, or have ambiguous effects on new technology adoption (e.g., Parente and Prescott, 2000; McCalman, 2001; Kanwar and Evenson, 2003; Javorcik, 2004; Connolly and Valderrama, 2005; Branstetter et al., 2006; Falvey et al., 2006; Manca, 2010; Branstetter et al., 2011).¹ Lai et al. (2020) provide a theoretical and empirical evidence that more rigorous IPR enforcement induces greater technology adoption (and innovation) in China.

A related but parallel literature focuses on culture and economic outcomes (for a survey, see Alesina and Giuliano, 2015). Guiso et al. (2006) define culture as the “customary beliefs and values that ethnic, religious, and social groups transmit fairly unchanged from generation to generation.” We focus on individualism vs. collectivism, an important dimension of cultural variation (Oishi and Kisling, 2009). Fogli and Veldkamp (2019) argue that technology adoption occurs more slowly in collectivistic societies, where social networks are closed and contact with outsiders is suppressed. In individualistic countries, there is a greater openness to outsiders, new ideas, and risks, and individuals strive to stand out. Ang (2017), Ang et al. (2020), and Jayasekara (2021) also report that individualistic societies have more favorable attitudes towards technology and its adoption.

¹ On the role of political institutions for technology adoption, see, e.g., Acemoglu and Robinson (2000, 2005) and Cervellati et al. (2018).

We contribute to the literature by proposing that IPR regimes and cultural differences in the individualism vs. collectivism dimension jointly help explain the pattern of technology adoption. To our knowledge, we are the first to merge these hitherto separate strands of literature. Taking the findings of the existing literature into account, we hypothesize that strict IPR regimes are associated with more intense technology adoption, and this effect is greater in more individualistic societies. We also hypothesize that technology adoption is greater in more individualistic countries, and this effect is reinforced by stronger IPR protection. The argument is that IPR protection makes the transfer and adoption of new technologies possible and less risky, while at the same time interest in technology adoption is greater in individualistic countries.² These two forces are consequently hypothesized to be complements.³

Anecdotal evidence suggests that the 1995 TRIPS agreement had a stronger effect on technology adoption in individualistic Ireland compared to collectivist Greece and Portugal, e.g.⁴ Ireland's 1995-2000 per capita average technology adoption was 82% higher than in the 1980-1994 period, while Greece and Portugal experienced increases of 66% and 64%, respectively (Comin and Hobijn, 2009).

To test our hypotheses empirically, we utilize data for 83 countries and 24 technologies for the period 1980 to 2000 from the Cross-country Historical

² History provides some further motivation and support for our hypotheses. The interplay of culture and institutions protecting property rights was a crucial factor for England's success (compared to France, the technological leader in Europe in the 17th century) in the 18th century. England had more decentralized institutions, protection of private property rights, and a superior patent system (North, 1981; North and Weingast, 1989; Dunphy et al., 1995; Mokyr, 2008). These institutions were combined with individualism and pro-technology philosophy that was accepted by the Anglican church under Protestantism, as opposed to the suppression of individualism and technology by the Catholic church in France (Dunphy et al., 1995; Temin, 1997). However, British society later became "culturally backward," averse to entrepreneurship and risk taking (Ruttan, 1988; Dunphy et al., 1994). Institutional barriers coupled with cultural backwardness led to a decline in technological superiority. In contrast, the U.S. celebrated individualism, encouraged risk taking, and promoted intellectual freedom (Temin, 1997). Several measures were taken to remove institutional barriers to technology innovation and adoption, e.g., the enhancement of property rights and a favorable patent system (Dunphy and Herbig, 1994; Mokyr (2008)). Dunphy and Herbig (1994) argue that the interaction between socio-cultural effects and economic and political institutions caused the U.S. to become the technological leader in the twentieth century.

³ Our hypotheses are reminiscent of Bisin and Verdier 's (2017), who argue that culture and institutions may serve as complements or substitutes, depending on existing economic conditions.

⁴ According to Hofstede et al. (2010), Ireland has an individualism score of 70, while Greece and Portugal have 35 and 27, respectively (a higher score implies higher individualism).

Adoption of Technology (CHAT) database developed by Comin and Hobijn (2009). The individualism measures come from Hofstede et al. (2010), the IPR protection index from Ginarte and Park (1997) and Park (2008). Our approach essentially compares technology adoption in individualist and collectivist countries with strong IPR against those with weak IPR protection (see also Cervellati et al. (2018); Nunn et al. (2018)).

We find that both greater IPR protection and individualism exert positive effects on technology adoption, and that these are mutually reinforcing, i.e., complements. This has not previously been shown in the literature. Stronger IPR protection has a positive effect on adoption, especially where the degree of individualism is high. Similarly, greater individualism raises technology adoption, particularly where IPR protection is strict. The effects are economically meaningful. Our baseline estimate suggests that the marginal effect of high, rather than low, individualism when the IPR regime is strong equals a 0.56 standard deviation higher technology adoption. However, if the IPR regime is weak, this effect is only 0.18 standard deviation. The effects of high and low IPR regime with different levels of individualism are of similar size. Our results are robust to a battery of alternative specifications. A reverse causality test rules out the notion that technology could influence IPR regimes or culture.

Our results suggest that future estimations of the effect of IPR regimes should take cultural traits into account, and conversely that work on the effect of individualism vs. collectivism should incorporate the influence of institutions such as IPR protection. Estimates that do not take the interaction effect into account may be biased. Policymakers should be aware that the effects of IPR reforms are conditional on the level of individualism.

The paper is organized as follows. Section 1.2 provides a literature review and the conceptual framework. Section 1.3 describes the data sources and the estimation strategy. Section 1.4 presents the results, and section 1.5 provides robustness checks. Section 1.6 presents some additional consistent findings on innovation, and section 1.7 concludes.

1.2. Related Literature and Conceptual Framework

The literature linking IPR regimes and technology adoption and innovation is continually expanding.⁵ Parente and Prescott (2000) argue that institutional arrangements related to IPR protection act as a legal mechanism to protect new ideas from exploitation, free riding and imitation. It assigns artificial monopoly powers to technology inventors and assures large monetary compensations when misused. Branstetter et al. (2006), and Kanwar and Evenson (2003) cross-country studies shows that technology innovation improves when countries have access to strong IPR protection. Therefore, positive effects of IPR on innovation is well established.

However, a stricter property rights regime may have an ambiguous effect on technology adoption. From a technology catch-up framework, overall effect of IPR on technology adoption largely depends on the development stage of the imitator. Tighter protection of property rights creates institutional barriers to technology adoption and diffusion, and this effect is more negative for technology imitators further away from the technology frontier (Parente and Prescott, 2000; Connolly and Valderrama, 2005; Falvey et al., 2006; Manca, 2010). However, having too little IPR protection could also hamper technology adoption, as followers will continuously fall behind and never catch-up.

Branstetter and Saggi (2011) suggest that strong IPRs stimulate industrial development in developing countries as multinationals relocate production, and thus transfer their technologies. Branstetter et al. (2006) study how technology transfers within U.S. multinational firms changed in response to IPR changes undertaken over the 1982-1999 period by 16 countries. U.S. multinationals responded to IPR regime reforms abroad by increasing technology transfers to these countries. Javorcik (2004) uses firm level data from the former Soviet Union and Eastern Europe, and find that strong IPR regimes encourage foreign direct investments in technology-intensive sectors that are reliant on IPRs. Maskus (2012) reports that stronger IPR regimes induce inward technology transfers via high-technology imports, licensing, and foreign direct investment. Delgado et al. (2013) explore how the implementation of intellectual property rights in developing

⁵ Innovation and technology adoption are interconnected but different concepts. We include innovation in the discussion when warranted. Section 6 presents additional findings on innovation.

countries under the 1995 TRIPS agreement affected trade in knowledge-intensive goods. Using data for 1993–2009, they find that imports of knowledge-intensive goods by developing countries was concentrated in the information and communications technology sector.⁶ Thus, the effect of TRIPS on knowledge diffusion to developing countries varied by sector. Krammer (2015) observes that developed nations are better able to take advantage of strong IPR protection relative to transition economies. Lai et al.'s (2020) theoretical model predicts that more rigorous IPR enforcement induces greater technology adoption and innovation. Their empirical evidence using Chinese firm-level cross-provincial data for 1998–2007 supports this prediction.

In this paper, we merge the IPR literature discussed above with the literature on culture, in particular the difference between individualism vs. collectivism which is a major dimension of cultural variation (Oishi and Kisling, 2009; Triandis, 2001; Talhelm et al., 2014). Individualism favors personal freedom, self-reliance, personal choice, risk-taking and achievement (see, e.g., Waterman, 1981; Sampson, 1988; Markus and Kitayama, 1991; Iyengar and Lepper, 1999; Snibbe and Markus, 2005; Kitayama et al., 2006; Gorodnichenko and Roland, 2012). In contrast, collectivism values conformity, cooperation, hierarchy, interdependence, and solidarity (Triandis, 1995; Brewer and Chen, 2007).

Landes (2006) suggests that China's failure to initiate the industrial revolution was due to a lack of cultural traits that favored the adoption of new inventions. Tabellini (2010) finds that the historical determinants of culture are strongly correlated with differences in European regional economic development. Bass (1969, 2004) classifies individual adopters of new technology into innovators, early adopters, early majority, late majority, and laggards (Ang et al., 2020). Innovators adopt an innovation early on, independently of others' decisions. Their technology adoption decision is formed by self-perception and self-interest, and they will adopt if the performance of a new technology is deemed sufficiently high.

⁶ After Singapore's software copyright laws were aligned with international laws in 1987, joint ventures between local and foreign firms stimulated technology spillovers (Uphoff, 1990). Singapore was once known for an absence of protection for foreign firms' copyrights. A Singapore government announcement in 1981 to focus on software development through strategic alliances with foreign software firms failed when American firms refused to collaborate with local firms due to weak IPRs. The subsequent 1987 IPR reforms were copied by Malaysia (Uphoff, 1990).

Thus, individualistic traits are associated with early technology adoption according to Bass. Consistent with this view, Ang (2017) shows a positive effect of individualism on technology adoption, and Jayasekara (2021) similarly finds that individualistic societies have developed more favorable attitudes towards technology. Ang et al. (2020) provide individual level evidence that individualists are more likely to adopt clean energy systems for transport and household use. Fogli and Veldkamp (2019) find that cultural patterns related to social networks affect technology diffusion. Collectivistic societies characterized by small, stable, localized networks are insular and with limited connections to outside networks. Thus, technology disseminates slowly in collectivistic societies.⁷

The previous literature predominantly finds that stronger IPR protection is associated with increased technology adoption. Moreover, individualistic individuals and societies are more open to new technologies. Building on these findings, we hypothesize that a stronger IPR regime is associated with greater rates of technology adoption, and the effect is reinforced in more individualistic countries which favor novel technologies. Conversely, the positive effect of individualism on technology adoption should be greater in countries with stronger IPR regimes. Strong IPR protection and individualism should be complements in the tendency to raise technology adoption rates.

1.3. Empirical Strategy and Data

1.3.1. Regression Model

The main goal of this paper is to examine how individualism and IPR protection jointly affects technology adoption. Hence, the following model is estimated:

$$\text{Log}(\text{TechAdop}_{ijt}) = \beta_0 + \beta_1 \text{IDV}_j + \beta_2 \text{IPR}_{jt} + \beta_3 (\text{IDV}_j * \text{IPR}_{jt}) + v_{jt} + v_{it} + \varepsilon_{ijt} \quad (1)$$

where $\text{Log}(\text{TechAdop}_{ijt})$ is the log of the scaled intensive margin of *technology_i* in country *j* at time *t*. A binary classification is adopted for our main independent

⁷ Innovation rates tend to be greater in individualistic cultures. Mokyr (2002) argues that innovation is an act against tradition and conformity and this implies that a culture of individualism should foster technological development. Gorodnichenko and Roland (2017) find a positive association between individualism and innovation (see also Shane, 1992, 1993; Taylor and Wilson, 2012; Zhu et al., 2019).

variables. IDV_j is a time invariant individualism dummy, which takes a value of unity for high individualism scores (above the median), and zero otherwise. IPR_{jt} is a time varying dummy variable, which takes the value one if country j has a strong intellectual property rights regime at time t , and zero otherwise. A possible interaction between individualism and IPR regime is captured by $IDV_j * IPR_{jt}$.

In order to control for confounding effects, specification (1) includes a full set of technology year fixed effects (v_{it}), as proposed by Comin and Hobijn (2009). The model also includes country year fixed effects (v_{jt}) to control for time variant differences across countries. Standard errors are adjusted for clustering at the country level. We do not include country fixed effects since these would control for time invariant country specific heterogeneity caused by, e.g., geography and time invariant cultural measures such as individualism.

1.3.2. Data

Table 1.A.1 in the appendix provides definitions and sources for all variables used, and Table 1.A.2 provides descriptive statistics.

(i) Dependent Variable: $\text{Log}(\text{TechAdopt})$

The main source of technology adoption data is from the Cross-country Historical Adoption of Technology (CHAT) database by Comin and Hobijn (2009). Measures of individual technologies can be of two types; intensive or extensive technology margins. The extensive margin measure reflects the fraction of potential adopters that have implemented a given technology (e.g. the fraction of farmers who use a tractor). Alternatively, the intensive margin measure captures the number of units of a new technology used by potential users. This is a better reflection of the actual level of technology adoption, in our view. It counts the number of units of a particular technology in the economy (e.g., number of cell phones), or the number of units of a given output produced by a new technology (e.g., tons of crude steel produced by the Bessemer process). According to Comin and Hobijn (2009), the advantages of using a measure of the intensive margin compared to the extensive margin are: (1) intensive margins do not require the identification of potential initial adopters; (2) intensive margins capture variations in capital deepening; and (3) intensive margins avoid the need for micro level data.

Using intensive margins provided by the CHAT database, the dependent variable is constructed by scaling the intensive margin by population and then log transforming it. This removes the units of the technology measures rendering them comparable across technologies (Comin and Hobijn, 2009). It is the only data source available reporting annual intensive margins for a variety of technologies. We have data for years 1980 to 2000 on 24 technologies from the transportation, communication and IT, industrial, agricultural, and medical sectors, as in Comin and Mestieri (2018) (see also Table 1.A.3 in the appendix). Note that the quality of technologies increases over time as successive generations of innovations occurs, as discussed in the seminal work by Norton and Bass (1987) and the recent literature review by Dhakal et al. (2019). Thus, IPR matters even for a technology that was originally developed long ago, as firms and countries explore how to imitate the product, improve the quality of the product, etc. For example, cell phones (a technology considered in the paper) have new features and product improvements in every generation. IPR plays an important role in protecting such patents, designs, etc.

Figure 1.1 illustrates how overall level of technology adoption varies across countries. To illustrate the magnitude of technology adoption using a map, we created a country-level technology adoption index by computing the average of standardized technology adoption intensities across the 24 technologies.

(ii) Individualism

The most widely and extensively used individualism scores are constructed by Hofstede et al. (2010), covering approximately 100 countries. Hofstede et al. (2010) define individualism as “the degree of interdependence a society maintains among its members”. Figure 1.2 depicts the overall distribution of Hofstede’s individualism score across countries. The United States, Canada, Australia, New Zealand, Norway, Sweden, Finland, and Spain are the most individualistic societies. We define a country as individualistic if it has an individualism score higher than the median sample score (30). Out of 83 countries in the baseline sample, 41 are individualistic countries and the remaining 42 are collectivist countries. Time series data on individualism at the country level are unavailable. However, since cultural traits evolve slowly, it appears reasonable to assume that individualism remains

unchanged during the 20-year period considered in this analysis. See Table 1.A.4 in the appendix for country classifications.

(iii) Intellectual Property Rights Protection

Data for IPR regime comes from the intellectual property rights index constructed by Ginarte and Park (1997), which covers 110 countries between the years 1960 and 1990, and extended to 2005 by Park (2008). The index examines patent laws along five major areas: (1) country's ability to issue patents along areas such as pharmaceuticals, chemicals, food, etc.; (2) participation in international patent agreements;⁸ (3) provisions for loss of protection through exploitation, compulsory licensing, and revocation of patents; (4) the adequacy of law enforcement; and (5) the duration of protection (Ginarte and Park, 1997). Each category represents a dichotomous variable, and the weighted sum across the five categories forms the index. Hence, it varies from 0 to 5. Values for the IPR index are available at a five interval for years 1960 to 2005. Since our analysis requires annual data, we construct annual IPR scores by linear interpolation.

Overall, the baseline sample contains 20,782 observations for 83 countries and 24 technologies for the period of 1980 to 2000. The panel dataset is unbalanced because all countries do not produce all 24 technologies during this time period. We classify a country as having a strong IPR regime if the IPR score in a particular year is greater than the median score, otherwise the country has weak IPR protection. The median IPR score between 1980 and 2000 is 2.37. The sample has 19 countries with consistently low IPR protection throughout the sample period. 23 countries have high IPR protection during this period. The remaining 41 countries switched IPR regime from low to high protection during the 1980 to 2000 time period. Figure 1.3 illustrates the distribution of the IPR index across countries in year 2000. United States, Belgium, Denmark, France, and Germany have the strongest IPR protection regimes. See Table 1.A.4 for more details.

According to Cervellati et al. (2018), adopting a dichotomous classification enables us to compare within country variation in IPR regime changes and its interplay with individualism on technology adoption over time, rather than

⁸ International patent agreements include the 1883 Paris Convention, the 1961 International Convention for the Protection of New Varieties of Plants (UPOV), and the 1970 Patent Cooperation Treaty (PCT).

accounting for cross country variations in IPR and individualism on technology adoption.

(iv) Control variables

Our control variables include education (human capital), democracy, trade liberalization, and GDP per capita. Education is measured by the human capital index (Penn World Tables (Version 9), which considers both years of schooling and returns to education. Democracy is reflected by Polity2 from the Quality of Governance (QoG, 2016) database. GDP per capita comes from WDI (2017). Wacziarg and Welch (2008) report the year of trade liberalization for 118 countries, using Sachs and Warner (1995) indicators of trade openness; trade liberalization here is a dichotomous variable indicating whether a country is open to trade or not in a given year. Table 1.1 provides the correlations between $\text{Log}(\text{TechAdop}_{ijt})$ and our control variables. In the subsequent robustness analysis, we also utilize the worldwide governance indicators, geographic controls, and measures of patent stocks, legal systems, and historical effects.

Table 1.1: Correlation matrix for baseline sample

	Log (TechAd _{ijt})	IPR _{jt}	Indivi- dualism	Individualism × IPR _{jt}	Education	Democracy	Trade lib.
Log(TechAd _{ijt})	1.000						
IPR _{jt}	0.369	1.000					
Individualism	0.229	0.525	1.000				
Individualism × IPR _{jt}	0.323	0.720	0.835	1.000			
Education	0.428	0.662	0.592	0.656	1.000		
Democracy	0.307	0.491	0.596	0.675	0.579	1.000	
Trade lib.	0.372	0.503	0.321	0.440	0.504	0.446	1.0000
GDP per capita	0.334	0.629	0.634	0.692	0.703	0.669	0.5314

Note: The baseline sample contains 20,782 observations from 83 countries and 24 technologies for the period 1980-2000.

Figure 1.1: Distribution of Technology adoption in 2000

Note: The overall technology adoption index for 83 countries. The index is computed as the average of standardized technology adoption levels across all technologies. Darker shades represent higher levels of technology adoption. The standardized technology adoption level for each technology is computed by scaling the technology adoption variable by population and the per capita values log transformed.

Figure 1.2: Distribution of the Individualism index

Note: The distribution of the individualism index across 101 countries for which data is available from Hofstede et al. (2010). Darker shades represent greater individualism.

Figure 1.3: Distribution of the Intellectual Property Rights index in year 2000

Note: The distribution of the IPR index for year 2000 across 116 countries for which data is available. The IPR data come from Ginarte and Park (1997) and Park (2008). Darker shades represent greater IPR protection.

1.4. Main Results

Table 1.2 presents the preliminary ordinary least square (OLS) regression estimates. All columns include technology $\times$ year fixed effects.⁹ Column (1) shows a positive direct relationship between individualism and technology adoption, significant at the 1% level. Individualistic societies tend to have higher levels of technology adoption compared to collectivist societies. Column (2) suggests that a strong IPR regime has a similar effect on technology adoption. The positive effects of individualism and IPR protection remain precisely estimated when entered simultaneously in column (3). Column (4) includes the interaction term of interest, which is positive and significant at the 10% level. Column (5) adds country $\times$ year fixed effects to account for time varying technology effects and country effects.¹⁰

⁹ Comin and Hobjin (2009) note that a full set of technology $\times$ year dummies removes the average diffusion path for a technology across countries, and that this captures externalities, sunk costs, etc., which affect the diffusion path. This is possible because CHAT data is three-dimensional and varies at the year, country, and technology levels.

¹⁰ Since individualism is time invariant, we include country $\times$ year fixed effects. The models do not suffer from issues such as a high degree of multicollinearity. In unreported results (available upon request), the interaction between individualism and IPR remain positively significant to an alternative model that includes IPR and the interaction between

Column (5) is our baseline model. Column (5) is consistent with the earlier models, and highlights the importance of the interaction between individualism and IPR protection. The significance level rises to 1% for the three variables of interest while the magnitude of the interaction coefficient doubles. The positive effect of individualism on technology adoption is enhanced by strong IPR protection. Similarly, while the effect of strong IPR protection on technology adoption is positive, the effect is greater in more individualistic countries.

Note that R-squared gradually rises as key variables and fixed effects are added sequentially. The effects of individualism and IPR regime appear economically significant. Column (5) suggests that the effect of having a high, rather than a low, level of individualism in a country with a strong IPR regime yields a 0.56 standard deviation greater level of our measure of technology adoption. This effect of high individualism equals 0.18 standard deviation if the IPR regime instead is weak. The effects of IPR under the different levels of individualism are of similar magnitudes.

Table 1.2: Ordinary least square estimates

Dep. Var. = Log(TechAdop _{ijt})	(1)	(2)	(3)	(4)	(5) Baseline model
Individualism	0.84*** (8.53)		0.62*** (5.47)	0.47** (3.23)	0.44*** (11.55)
IPR		0.78*** (9.35)	0.45*** (4.15)	0.28* (1.96)	0.45*** (43.65)
Individualism × IPR				0.32* (1.70)	0.89*** (20.84)
Tech × Year FE	Yes	Yes	Yes	Yes	Yes
Country × Year FE	No	No	No	No	Yes
Observations	20,782	20,782	20,782	20,782	20,782
No. of Countries	83	83	83	83	83
R-squared	0.90	0.89	0.91	0.91	0.94

Notes: This table presents the ordinary least square estimates for the effect of individualism, intellectual property rights and their interaction term on technology adoption. The numbers in parentheses are t-statistics based on robust standard errors clustered at the country level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. The dependent variable is the log transformed standardized technology adoption level (CHAT Dataset). Individualism is the individualism index (Hofstede et al., 2010). IPR is to the Intellectual Property Rights index (Ginarte and Park, 1997; Park, 2008).

individualism and IPR on technology adoption in the presence of country fixed effects. However, IPR is insignificant.

1.5. Robustness Analysis

In order to assess the robustness of the preliminary regression results, we investigate several alternative models with respect to the baseline model.¹¹ The appendix (Table 1.A.1) provides a detailed explanation of all variables and their sources.

1.5.1 Reverse Causality

Reverse causality is a concern if improvements in technology adoption affect cultural orientation and facilitate different IPR regimes. Since we use the time invariant individualism score by Hofstede et al. (2010), the level of individualism is not affected by technology adoption. However, one may argue that IPR protection may improve over time with greater technology sophistication, such that technology adopters may exploit monopolistic powers. In order to control for reverse causality, in Table 1.3 we regress IPR protection between 1990 and 2000 on technology adoption between 1980 and 1990, with our control variables included. The results in Table 1.3 indicate that technology adoption does not affect IPR protection.

Table 1.3: Test of reverse causality

Dep. Var.= IPR between 1990-2000	(1)	(2)	(3)	(4)
Technology adoption (1980-1990)	-0.09 (-0.98)	-0.08 (-0.69)	-0.04 (-0.47)	-0.12 (-1.32)
GDP per capita		0.18 (1.10)	0.31 (1.09)	-0.25 (-0.72)
Democracy		-0.02 (-0.33)	-0.03 (-0.50)	-0.11* (-1.74)
Education		1.36*** (7.20)	3.16*** (8.28)	1.37*** (2.91)
Trade liberalization		0.33*** (2.80)	0.17 (1.25)	-0.03 (-0.21)
Country FE	Yes	No	Yes	Yes
Year FE	Yes	No	No	Yes
Observations	822	822	822	822
No. of Countries	76	76	76	76
R-squared	0.94	0.63	0.93	0.94

Notes: This table presents the results of the effect of technology adoption on intellectual property rights as a test of reverse causality. The numbers in parentheses are t-statistics, based on robust standard errors clustered at the country level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. The dependent variable is the interpolated IPR index by Ginarte and Park (1997) between 1990-2000 in continuous form. IPR is categorized by country. Thus, technology adoption is constructed by taking the average of Log(TechAdop_{ijt}) across 24 technologies in order to

¹¹ In our framework, IPR regime changes take place in different years for different countries. Hence, testing for the common trend assumption is not plausible here.

form a single index for each country that vary cross time but not technology. Both IPR and technology adoption variables use annual data for 1980-1990.

1.5.2 Industry Sectors

In order to investigate whether our results are driven by any particular technology, we first categorize technologies into five different industry sectors, see Table 1.A.3 for details. We then iteratively drop one industry sector at a time (studying one industry, or a subset of industries, at a time is infeasible due to sample size and the larger number of fixed effects). Columns (1) to (5) in Table 1.4 present estimations with technologies related to transport, communication and IT, medical, agriculture, and industrial sectors dropped from the sample, respectively. The results are consistent with the baseline findings. This reaffirms that our results are not driven by a specific industry or technology. R-squared declines in column (5), suggesting that the industrial sector provides relatively strong support for our hypothesis.

Table 1.4: OLS estimates for different industry technology exclusions

FBR	(1)	(2)	(3)	(4)	(5)
Dep. Var. = Log(TechAd _{ijt})	Exclude Transportation Sector	Exclude Communication & IT Sector	Exclude Medical Sector	Exclude Agriculture Sector	Exclude Industrial Sector
Individualism	0.77*** (20.73)	0.46*** (13.36)	0.43*** (11.56)	0.27*** (5.10)	0.35*** (7.71)
IPR	0.46*** (38.21)	0.68*** (27.91)	0.45*** (43.80)	0.18*** (13.27)	0.55*** (96.17)
Individualism × IPR	0.58*** (13.18)	0.52*** (11.56)	0.85*** (20.18)	1.41*** (24.35)	0.93*** (17.74)
Tech × Year FE	Yes	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes	Yes
Observations	12,913	16,075	19,410	17,784	16,946
No. of Countries	83	83	83	83	83
R-squared	0.98	0.94	0.94	0.95	0.87

Notes: This table presents the ordinary least square estimates for the effect of individualism, intellectual property rights and their interaction term on technology adoption. The numbers in parentheses are t-statistics and are based on robust standard errors clustered at the country level. ***, **, and * indicates that the coefficient is significant at the 1%, 5%, and 10% level, respectively. The dependent variable is the log transformed standardized technology adoption level (CHAT Dataset). Individualism is the individualism index (Hofstede et al., 2010). IPR is to the Intellectual Property Rights Index (Ginarte and Park, 1997; Park, 2008). Each column excludes technologies from a particular sector. Column (1), (2), (3), (4) and (5) excludes technology from the transportation, communication and IT, medical, agricultural and industrial sector, respectively. See Table 1.A.3 for categorization of technologies into different industries.

1.5.3 Alternative Estimation Intervals

The baseline model uses the interpolated IPR index by Ginarte and Park (1997). To rule out possible influence from business cycles and to mitigate transitional dynamics, column (1) of Table 1.5 presents the result of the baseline model re-estimated using the original IPR index constructed with a five-year interval. The findings remain consistent. To further filter out any effects from transitional dynamics, we replicate the baseline analysis but divide the full sample period into two 10-year subsamples, 1980-1990 and 1990-2000, respectively. The results in columns (2) and (3) are in line with the main results. However, the IPR coefficient is negative for the period 1980-1990 (column (2)). This sheds some light on the debate surrounding the 1995 Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS), which required members of the World Trade Organization to comply with a set of IPR minimum standards. Advocates of weak IPR standards appear to have been correct that strong IPRs restrict the ability of local firms to adopt and build on foreign firms' technologies during the early stages of industrialization. For example, in the 1980s learning primarily took place through reverse engineering and technology imitation (see, e.g., Maskus, 2000; Manca, 2010). Strong IPR protection becomes a positive element only once a country gains sufficient technological expertise and own indigenous capabilities. Consistent with the above discussion for the 1980s, the IPR coefficient is similarly negative for the 1970-1980 time period (results not reported, available upon request).¹² The effect of IPR standards reversed during the 1990s (and the 1980-2000 time period overall), however, as production of technologically advanced goods expanded towards IPR-reforming countries, especially those with an individualistic culture.

¹² The analysis excludes years 1970-1979 because data is missing or scant for five technologies.

1.5.4 Alternative Individualism and IPR Measures

Next, we use an alternative individualism score by Suh et al. (1998) to check the sensitivity of the baseline results. The index uses data from two international surveys, namely the World Value Survey and the International College Student Data (ICSD) survey.¹³ Data are available for 50 countries. The correlation with Hofstede's measure is 0.87. Although the sample size declines, the estimate in column (4) of Table 1.5 remains consistent. Column (5) uses the IPR enforcement index by Papageorgiadis and Sofka (2020) as an alternative measure (see also Papageorgiadis et al., 2019). It is constructed using firm level transaction costs associated with patent enforcement (e.g. servicing costs, property rights protection costs involved with judicial enforcements, and monitoring costs) and firm level litigation decisions and outcomes related to patents. This IPR enforcement index is available from 1998 onwards only. Therefore, the sample size in column (5) is restricted to 1998 to 2000. Despite the lower number of observations, two of the three coefficients of interest remain significant and positive.

1.5.5 OECD vs. non-OECD

We also investigate whether our results are driven by a group of countries, in particular technologically sophisticated OECD (innovators) and technologically less sophisticated non-OECD (imitators) countries. According to columns (6) and (7) in Table 1.5, a stronger IPR regime has a positive effect on both developed and developing countries. However, the interaction between IPR and individualism is insignificant for non-OECD countries in column (7). The level of IPR enforcement in non-OECD countries may not be sufficiently strong for individualism to exert a positive effect. Conversely, non-OECD countries may not be sufficiently individualistic to enable IPR to exert a positive effect.

¹³ The index builds on the notion that emotional experiences have a more profound influence on life satisfaction in individualistic cultures than in collectivist cultures (Suh et al., 1998).

Table 1.5: Alternative intervals, measurements, and categorization

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. Var. = Log(TechAd _{ijt})	5 yearly data	1980-1990	1990- 2000	Suh et al. (1998)	Papageorgiadis and Sofka (2020)	OECD	Non- OECD
Individualism	0.65*** (15.66)	0.70*** (15.47)	0.44*** (11.51)	0.52*** (33.83)	0.051** (2.21)	0.17*** (10.86)	0.63*** (10.25)
IPR	0.45*** (43.63)	-0.26*** (-9.63)	0.46*** (43.48)	0.52*** (26.76)	-0.004 (-0.20)	0.36*** (46.17)	0.44*** (26.44)
Individualism × IPR	0.68*** (14.83)	0.84*** (18.30)	0.89*** (20.75)	0.28*** (17.81)	0.718*** (19.53)	0.62*** (37.21)	-0.02 (-0.29)
Tech × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geo. controls	No	No	No	No	No	No	No
Observations	4,909	10,642	10,140	13,779	1,491	10,077	10,705
No. of Countries	83	83	83	50	42	32	51
R-squared	0.94	0.93	0.95	0.94	0.97	0.95	0.94

Notes: This table presents the ordinary least square estimates for the effect of individualism, intellectual property rights and their interaction term on technology adoption. The numbers in parentheses are t-statistics and are based on robust standard errors clustered at the country level. ***, **, and * indicates that the coefficient is significant at the 1%, 5%, and 10% level, respectively. The dependent variable is the log transformed standardized technology adoption level (CHAT Dataset). Individualism is the individualism index from Hofstede et al. (2010). IPR is to the Intellectual Property Rights Index from Ginarte and Park (1997) and Park (2008). Column (1) shows the results for the IPR index constructed at 5-year intervals. Columns (2) and (3) replicate the baseline analysis for the periods 1980-1990 and 1990-2000, respectively. In Column (4) *Individualism* is Suh et al.'s (1998) individualism score. Column (5) uses the IPR enforcement score by Papageorgiadis and Sofka (2020). Columns (6) and (7) group countries by OECD and non-OECD membership, respectively.

1.5.6 Control for Patent Stock

Research and development (R&D) plays a key role in promoting technology adoption through knowledge spillover, both domestic and international (Griffith et al. 2004). We control for initial patent stock in order to mitigate any bias that may arise from an initial stock of ideas or knowledge. We use patent applications as a measure of R&D output (Ang and Madsen, 2015). Column (1) in Table 1.6 confirms the positive effects of individualism, IPR, and their interaction on technology adoption.

1.5.7 Control for Additional Economic Variables

Column (2) controls for education (human capital), democracy, trade liberalization, and GDP per capita. Knowledge endowment and the efficiency of the executive are major drivers of technology adoption (Comin and Mestieri, 2018). Trade liberalization reduces entry barriers for new entrepreneurs, supporting knowledge spillovers, and technology adoption (Acemoglu, 2008). Wealthier economies have higher resource endowments and are more likely to invest in new technologies. In column (3) we use night light intensity in 2010 as an alternative

measure of the size of the economy. The main results remain largely intact in columns (2) and (3) of Table 1.6.

1.5.8 Control for Geographic Variables

Talhelm et al. (2014) find a strong relationship between cultural norms and agricultural practices, driven by geographical and ecological factors. For instance, farming communities engaged in cooperative management of water systems tend to be more collaborative, with strict preferences for obedience. This leads to more collectivist cultural norms. Conversely, communities in elevated rugged areas with abundant rainfall require less cooperation among farming groups, which led to individualistic behavior over time. To isolate the effect of individualism on technology adoption, column (4) of Table 1.6 includes a series of geographic and climate conditions such as mean temperature (annual data), annual precipitation, mean elevation, and landlockedness. Overall, the results are consistent with our main findings.

1.5.9 Control for Historical Effects

Legal origins affect multiple economic outcomes (La Porta et al., 1998; Fredriksson and Sauquet, 2017). Including British, German, and Scandinavian legal origins (French legal origin is the excluded category) in column (5), Table 1.6, helps isolate the exogenous effect of IPR on technology adoption. The main insights remain. Next, Comin et al. (2010) find that technology adoption has persistent effects. Hence, early technology adoption may affect current levels of technology adoption. Although the empirical specification in Eqn. (1) controls for possible sector specific trends by adding technology year fixed effects, including the technology adoption level in 1500AD (Comin et al., 2010) helps isolate the exogenous variation in current levels of technology adoption. The results remain intact in column (6). Finally, we control for the timing of agriculture transition, following Ashraf and Galor (2011). Since switching from pastoralism to sedentary agriculture practices requires sufficient know-how and skills concerning crop cultivation, societies that practiced early farming techniques are likely to experience higher technology adoption rates in later stages of development. In column (7) we

include the measure of the timing of agriculture transition constructed by Putterman (2006), which reaffirms our main results.

1.5.10 Control for Lagged GDP per capita

So far, no consideration has been given to GDP per capita being endogenous. To address this, column (8) includes GDP per capita lagged one year. Our main results remain robust. In unreported results (available upon request), our results remain highly significant when alternatively using GDP per capita lagged 5, 10, and 20 years, respectively.

Table 1.6: Robustness to contemporary and historical effects

Dep. Var. = Log(TechAd _{ijt})	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Patent Stock	Econ. controls	Light intensity	Geo. controls	Legal origin	Tech 1500AD	Agri. Transition	Lagged GDP
Individualism	0.42*** (8.36)	1.144*** (7.767)	0.079 (0.512)	4.091** (2.538)	0.47*** (7.66)	0.33*** (5.57)	0.37*** (6.77)	13.106* (1.688)
IPR	0.43*** (21.99)	1.608*** (8.751)	0.153*** (10.580)	0.191** (2.053)	0.48*** (12.70)	0.42*** (20.96)	0.42*** (20.96)	0.203*** (7.376)
Individualism × IPR	0.87*** (22.04)	4.723*** (7.216)	0.360*** (5.325)	17.036*** (2.943)	0.85*** (9.16)	1.06*** (14.23)	1.02*** (16.53)	13.445* (1.823)
Education		0.031 (0.287)	-0.557*** (-9.411)					-2.963* (-1.718)
Democracy		1.480*** (5.025)	0.089 (0.607)					-2.658 (-1.493)
Trade lib.		-0.944*** (-4.167)	0.191 (1.433)					1.940 (1.521)
GDP per cap.		-2.840*** (-5.386)						
Log(Patent Stock)	0.01 (1.07)							
Light intensity			1.280*** (6.181)					
British legal					0.02 (0.65)			
German legal					0.72** (3.24)			
Scand. legal					-0.05 (-1.33)			
Tech adopt 1500AD						0.04 (1.40)		
Agri. transition							0.04 (1.4)	
GDP per cap. (-1)								-0.020 (-0.812)
Tech × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geo. controls	No	No	No	Yes	No	No	No	Yes
Observations	19,472	18558	17632	18219	20,782	18,557	18,557	18218
No. of Countries	75	75	69	76	83	71	71	75
R-squared	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94

Notes: This table presents the ordinary least square estimates for the effect of individualism, intellectual property rights and their interaction term on technology adoption. The numbers in parentheses are t-statistics and are based

on robust standard errors clustered at the country level. ***, **, and * indicates that the coefficient is significant at the 1%, 5%, and 10% level, respectively. Column (1) controls for patent stock using patent applications as a measure of R&D output (Ang and Madsen, 2015). Columns (2) and (3) use standardized measures of education, democracy, GDP per capita, and night light intensity. The trade liberalization is a dichotomous variable which indicates whether the country experienced trade liberalization in year t . The geographic controls in column (4) includes annual mean temperature, annual precipitation, mean elevation, and landlockedness. Column (5) controls for British, German, and Scandinavian legal origins and columns (6) and (7) control for the technology adoption level in 1500AD and the timing of agricultural transition, respectively. Column (8) uses GDP per capita lagged one year. See Table 1.A.1 for detailed variable definitions.

1.5.11 Control for Additional Institutional Variables

In Table 1.7 we control for institutional variables using Worldwide Governance Indicators (WGI, 2017) for year 2000, in particular freedom of expression (voice and accountability), political stability, government effectiveness (quality of public services, policy formulation and implementation), regulatory quality, rule of law, and control of corruption. The results remain positive and highly significant in all cases.

Table 1.7: Worldwide Governance Indicators

Dep. Var. = Log(TechAd _{ijt})	Baseline model	(1)	(2)	(3)	(4)	(5)	(6)
Individualism	0.44** (11.55)	0.41*** (8.41)	0.43*** (11.94)	0.38*** (4.24)	0.43*** (11.50)	0.43*** (10.89)	0.41*** (8.61)
IPR	0.45*** (43.65)	0.47*** (15.64)	0.45*** (35.20)	0.44*** (14.39)	0.46*** (31.26)	0.45*** (39.95)	0.45*** (35.12)
Individualism × IPR	0.89*** (20.84)	0.87*** (12.64)	0.90*** (20.74)	0.87*** (12.26)	0.87*** (13.55)	0.89*** (14.34)	0.86*** (10.80)
Voice and Accountability		0.02 (0.65)					
Political Stability and Absence of violence			0.01 (0.65)				
Government Effectiveness				0.04 (0.65)			
Regulatory Quality					0.02 (0.65)		
Rule of Law						0.02 (0.65)	
Control of Corruption							0.03 (0.65)
Tech × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,782	20,782	20,782	20,782	20,782	20,782	20,782
No. of Countries	83	83	83	83	83	83	83
R-squared	0.94	0.94	0.94	0.94	0.94	0.94	0.94

Notes: This table presents the ordinary least square estimates for the effect of individualism, intellectual property rights and their interaction term on technology adoption. The numbers in parentheses are t-statistics and are based on robust standard errors clustered at the country level. ***, **, and * indicates that the coefficient is significant at the 1%, 5%, and 10% level, respectively. The dependent variable is the log transformed standardized technology adoption level (CHAT Dataset). Individualism is the individualism index (Hofstede et al., 2010). IPR is the Intellectual Property Rights Index (Ginarte and Park, 1997; Park, 2008). Columns (1)-(6) control for the six World Governance Indicators (year 2000), respectively: voice and accountability, political stability, government effectiveness, regulatory quality, rule of law and control of corruption.

1.5.12 Alternative Functional Forms for Individualism and IPR scores

The dichotomous classification of individualism and IPR may potentially drive our results. Instead, we therefore divide our individualism and IPR measures into three categorical variables (low (excluded category); moderate; high) using percentiles. The results presented in Table 1.8 suggest that the functional form does not drive our results. There is some evidence that the results are primarily driven by countries with the highest levels of individualism and IPR protection, as two coefficients reflecting moderate levels are insignificant.

Table 1.8: Alternative functional form for IDV and IPR scores

	(1)		(2)
Dep. Var. = Log(TechAd _{ijt})	IDV at 3 levels	Dep. Var. = Log(TechAd _{ijt})	IPR at 3 levels
Moderate Individualism	0.02 (0.65)	Individualism	0.32*** (6.46)
High Individualism	0.49*** (7.72)	Moderate IPR	0.46*** (43.65)
Moderate Individualism × IPR	0.70*** (19.19)	High IPR	1.03*** (50.63)
High Individualism × IPR	0.85*** (13.12)	Individualism × Moderate IPR	-0.03 (-0.75)
IPR	0.48*** (12.70)	Individualism × High IPR	0.45*** (9.52)
Tech × Year FE	Yes	Tech × Year FE	Yes
Country × Year FE	Yes	Country × Year FE	Yes
Observations	20,782	Observations	20,782
No. of Countries	83	No. of Countries	83
R-squared	0.94	R-squared	0.94

Notes: This table presents the ordinary least square estimates for the effect of individualism, intellectual property rights and their interaction term on technology adoption. The numbers in parentheses are t-statistics and are based on robust standard errors clustered at the country level. ***, **, and * indicates that the coefficient is significant at the 1%, 5%, and 10% level, respectively. The dependent variable is the log transformed standardized technology adoption level (CHAT Dataset). Individualism is the individualism index (Hofstede et al., 2010). IPR is to the Intellectual Property Rights Index (Ginarte and Park, 1997; Park, 2008). Column (1) utilizes three levels of individualism – low (excluded category), moderate and high. Similarly, column (2) shows the estimates for low (excluded category), moderate and high level of the IPR index.

1.5.13 Additional Robustness Check with Lagged IPR

All estimations reported above rely on model specifications that assume that IPR protection has contemporaneous effects on technology adoption. However, technology adoption may be based on an earlier year's IPR protection. In Table 1.9 we report results using IPR lagged by one, two and three time periods, respectively. The positive impacts of IPR and its interaction with individualism on technology adoption remain.

1.5.14 Other Robustness Checks

Since Hofstede's individualism measure is based on surveys, it could be affected by extreme responses. Therefore, in two models in Table 1.A.5 in the Appendix we exclude the top and bottom 5% and 15% ranked countries in terms of individualism, respectively. The results survive these exclusions and assert that extreme individualism scores do not affect the main results. Next, we include the interaction between individualism and time variable to the baseline model in order to create time-variation in the impact of individualism on technology adaption to account for the increasing adaption of technology across countries. Results are reported in Table 1.A.6.

Table 1.9: Ordinary least square estimates for lagged IPR

Dep. Var. = Log(TechAd _{ijt})	(1)	(2)	(3)
Individualism	1.00*** (46.27)	1.21*** (69.27)	1.25*** (80.40)
IPR(-1)	0.46*** (43.65)		
Individualism × IPR(-1)	0.34*** (9.99)		
IPR(-2)		0.46*** (43.65)	
Individualism × IPR(-2)		0.14*** (4.64)	
IPR(-3)			0.46*** (43.65)
Individualism × IPR(-3)			0.09** (3.26)
Tech × Year FE	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes
Observations	20,782	20,782	20,782
No. of Countries	83	83	83
R-squared	0.94	0.94	0.94

Notes: The numbers in parentheses are t-statistics and are based on robust standard errors clustered at the country level. The dependent variable is the log transformed standardized technology adoption level (CHAT Dataset). Individualism is the individualism index (Hofstede et al., 2010). IPR is to the Intellectual Property Rights Index (Ginarte and Park, 1997; Park, 2008). ***, **, and * indicates that the coefficient is significant at the 1%, 5%, and 10% level, respectively. The IPR (-1), IPR (-2) and IPR (-3) variables are lagged by one, two and three time periods, respectively. The identical coefficients for IPR(-1), IPR(-2), and IPR(-3) are coincidental.

1.6 Additional Findings on Innovation

As an extension to our main results on technology adoption, we also test the effects of individualism, IPR protection, and their interaction with technology *innovation*. Patents granted is used as a proxy for technology innovation. Data on

patents granted come from USPTO (2017) and WIPO (2017). Since patents granted data are not classified by technology, the regressions exclude technology year fixed effects. Country year fixed effects are also excluded in order to cope with the loss of degrees of freedom caused by the small sample size. For completeness, we opt to present the results despite these data limitations. Overall, the results indicate the importance of individualism, IPR protection, and their interaction on technology innovation. The complete estimates are presented in Table 1.A.7 in the appendix.

1.7 Conclusion

The literature identifies technology adoption as an important driver of cross-country income and productivity differences. However, the underlying drivers of technology adoption remain unclear. This study contributes to the literature by hypothesizing that both the cultural trait of individualism and the level of intellectual property rights (IPR) protection are associated with cross-country variations in technology adoption. Using data on technology adoption measured by the intensive margin, we show that individualism has a positive effect on technology adoption, in particular when IPR protection is strong. That is, individualistic cultures that embrace new ideas and creativity are inclined to adopt new technologies and the incentives increase when societies have access to stronger IPR protection. Additionally, stronger IPR regimes have a positive effect on adoption, and the effect is reinforced in more individualistic countries. By no means we intend to rank cultures depending on how favorable they are towards technology adoption. We show that culture and IPR protection interacts and complements each other. Policy makers seeking to improve technology adoption should expect that the result of IPR reforms will depend on existing cultures. Therefore, IPR reforms that works for one country should not be exported and implemented off the shelf in another country. We believe that this research can facilitate conversations on technology adoption and diffusion especially with regards to various policy tools and their effectiveness under various cultural backgrounds. For example, multinational corporations seeking to relocate or transfer technology should focus on technologies that are culturally suitable and viable, while policy makers take measures to encourage creativity and risk-taking behaviors.

1.8 Appendix

Table 1.A.1: Definitions of variables and data sources

Variable	Description	Source
[A] Key variables		
Technology adoption	Technology adoption is measured by the intensive margin proposed by Comin and Hobijn (2009). The variable is scaled by population and log transformed to make it comparable across technologies. The intensive margins are reported annually.	CHAT database
Individualism	Individualism is a cultural aspect that values principles governing themselves and their immediate families, relative to collectivism that values tradition and conformity. The index ranges from 0 to 100, with a higher value corresponding to a more individualistic culture.	The Hofstede Centre
IPR	Intellectual property rights protection is an index formed by examining patent laws along five major areas that covers (1) extent of coverage, (2) membership in international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms, and (5) duration of protection. Data is available for 110 countries in five-year intervals. Linear interpolation is used to construct annual scores between 1980 and 2000.	Ginarte and Park (1997) and Park (2008)
[B] Alternative individualism and IPR score		
Suh's individualism score	The index is constructed using World Value Survey and International College Student Data (ICSD). The conceptual framework stems on the idea that emotional experiences influence life satisfaction in individualist cultures than in collectivist cultures.	Suh et al. (1998)
IPR enforcement index	The index uses firm level transaction costs associated with patent enforcement (e.g., servicing costs, property rights protection costs involved with judicial enforcements, and monitoring costs) and firm level litigation decisions and outcomes to construct the index. Data is available from 1998 to 2017. We create an index for IPR enforcement using the median score.	Papageorgiadis and Sofka (2020)
[C] Control variables		
Education	Human Capital Index is constructed using data related to both years of schooling and returns to education. Data is available for 144 countries between 1950 and 2014. The standardized variable is used.	Penn World Tables, version 9.0

Democracy	Democracy is measured by polity2 index. Index ranges from 0-10 where 0 is least democratic and 10 most democratic. The standardized variable is used.	QoG (2016)
Trade liberalization	Trade liberalization dates are by Wacziarg and Welch (2008) based on Sachs and Warner (1995) trade openness indicators. For each country, the value 1 is given after trade liberalization and 0 prior to liberalization.	Wacziarg and Welch (2008)
GDP per capita	The gross domestic product is measured at current US\$ weighted by mid-year population. The standardized variable is used.	WDI (2017)
Light intensity in 2010	This is the log transformed night light intensity per capita in year 2010. The standardized variable is used.	G-ECON project
Patent Stock	Initial patent stock is created using the Solow model steady state value $\frac{A_0}{\delta+g}$. Here A_0 is the initial patent applications. δ is the depreciation rate, assumed as 15%. g is the annual geometric growth rate in patent applications. Patent data are taken from the World Intellectual Property Organization (WIPO).	WIPO
Worldwide Governance Indicators	WGI indicators are constructed across six dimensions. 1. Voice and Accountability 2. Political Stability and Absence of Violence 3. Government Effectiveness 4. Regulatory Quality 5. Rule of Law 6. Control of Corruption	WGI(2017)
[D] Geographic variables		
Total precipitation	The mean annual precipitation for each country.	Mitchell et al. (2004)
Elevation	The mean elevation of a country above sea level measured in km.	Gallup et al. (2010)
Mean temperature	The monthly mean temperatures are averaged to construct the annual average temperature for each country. The standardized values are used in the regressions.	Mitchell et al. (2004)
Land lockedness	A dummy variable that equals 1 if a country is fully surrounded by land and 0 otherwise.	Gallup et al. (2010)
[E] Historical effects and legal origin		
Technology adoption 1500AD	The average adoption levels of technology in 1500 AD covering the industries agriculture, transportation, communications, industry, and military.	Comin et al. (2010)
Agriculture timing	The number of years elapsed, in 2000 AD, since the transition to agriculture (in thousand years).	Ashraf and Galor (2011)
Legal origin	A dummy variable that identifies the legal tradition of a country as British, French or German or Scandinavian.	La Porta et al. (1998)

[F] Appendix Data		
Patents granted	Log of Patents granted per million population	USPTO and WIPO

Table 1.A.2: Summary of baseline variables

	Observations	Mean	Std. Dev.	Min	Max
Log(TechA)	20,782	-2.837	2.38716	-9.497	4.494
Individualism	20,782	0.489	0.499	0	1
IPR	20,782	0.492	0.499	0	1
GDP per capita	18,558	15461.25	16187.93	131.646	81709.66
Democracy	18,558	4.614	6.657	-10	10
Education	18,558	2.339	0.705	1.014	3.578
Trade liberalization	18,558	0.671	0.469	0	1

Table 1.A.3: Estimated Intensive Margin

	Technology	Industry	Obs.	Mean
1	Steel (Bessemer, Open Hearth)	Industrial	290	-4.89
2	Blast Oxygen Furnace	Industrial	777	-3.91
3	Electric Arc Furnace	Industrial	1,151	-4.45
4	Electricity	Industrial	1,618	3.11
5	Fertilizer	Agriculture	1,642	-1.79
6	Harvester	Agriculture	1,356	-3.53
7	Kidney Transplant	Medical	558	-4.72
8	Liver Transplant	Medical	330	-5.49
9	Heart Surgery	Medical	306	-5.57
10	Coronary bypass surgery	Medical	178	-3.41
11	Steam and Motor Ships	Transportation	524	-4.81
12	Railways Freight	Transportation	808	-4.25
13	Railways Passengers	Transportation	751	-3.20
14	Cars	Transportation	1,311	-1.25
15	Trucks	Transportation	1,130	-4.75
16	Tractor	Transportation	1,642	-2.63
17	Aviation Freight	Transportation	779	-5.22
18	Aviation Passengers	Transportation	924	-3.70
19	Telegraph	Communication & IT	545	-6.83
20	Mail	Communication & IT	636	-4.27
21	Telephone	Communication & IT	1,101	-1.18
22	Cellphones	Communication & IT	919	-2.18
23	Personal Computers	Communication & IT	840	-1.64
24	Internet users	Communication & IT	666	-2.35

Table 1.A.4: Individualism dummy and IPR status

No.	Country	IDV dummy	IPR status	No.	Country	IDV dummy	IPR status
1	Angola	0	Low	43	Luxembourg	1	High
2	Argentina	1	1996	44	Malawi	0	Low
3	Australia	1	High	45	Malaysia	0	1993
4	Austria	1	High	46	Mexico	0	1995
5	Bangladesh	0	Low	47	Morocco	1	1998
6	Belgium	1	High	48	Mozambique	0	Low
7	Brazil	1	1998	49	Nepal	0	Low
8	Bulgaria	0	1993	50	Netherlands	1	High
9	Burkina Faso	0	Low	51	New Zealand	1	1991
10	Canada	1	High	52	Nigeria	0	1991
11	Chile	0	1991	53	Norway	1	High
12	China	0	1997	54	Pakistan	0	Low
13	Colombia	0	1995	55	Panama	0	1998
14	Costa Rica	0	1999	56	Peru	0	1995
15	Czech Republic	1	1995	57	Philippines	0	1991
16	Denmark	1	High	58	Poland	1	1993
17	Dominican Rep.	0	Low	59	Portugal	0	1993
18	Ecuador	0	1997	60	Romania	0	1993
19	Egypt	0	Low	61	Russia	1	1993
20	El Salvador	0	1993	62	Saudi Arabia	0	Low
21	Ethiopia	0	Low	63	Senegal	0	Low
22	Finland	1	High	64	Sierra Leone	0	High
23	France	1	High	65	Singapore	0	1991
24	Germany	1	High	66	Slovak Republic	1	1994
25	Ghana	0	1994	67	South Africa	1	High
26	Greece	0	1986	68	South Korea	0	1983
27	Guatemala	0	Low	69	Spain	1	High
28	Honduras	0	1998	70	Sri Lanka	0	High
29	Hong Kong	0	High	71	Sweden	1	High
30	Hungary	1	1991	72	Switzerland	1	High
31	Iceland	1	1993	73	Syria	0	Low
32	India	1	Low	74	Taiwan	0	1993
33	Indonesia	0	2000	75	Tanzania	0	1996
34	Iran	1	Low	76	Thailand	0	Low
35	Iraq	0	Low	77	Turkey	0	1995
36	Ireland	1	1991	78	United Kingdom	1	High
37	Israel	1	High	79	United States	1	High
38	Italy	1	High	80	Uruguay	0	1997
39	Japan	1	High	81	Venezuela	0	1995
40	Jordan	0	2000	82	Vietnam	0	1995
41	Kenya	0	1995	83	Zambia	0	Low
42	Lithuania	1	1995				

Notes: A country is categorized as individualistic (1) if the Hofstede et al. (2010) individualism score is greater than the median score (30), else as collectivistic (0). A country has a high IPR regime if the Ginarte and Park (1997) IPR index exceeds the median score (2.37), else a low IPR regime. In the baseline sample (1980-2000), 19 have a low IPR regime,

23 have high IPR regime. The transition year is reported for countries that switched from low to high IPR regime.

Table 1.A.5: Excluding extreme individualism scores

	(1)	(2)
Dep. Var. = Log(TechAd _{ijt})	Exclude top and bottom 5% of IDV countries	Exclude top and bottom 15% of IDV countries
IPR	0.45*** (40.75)	0.44*** (32.31)
Individualism	0.43*** (10.79)	0.40*** (12.32)
Individualism × IPR	0.74*** (17.76)	0.32*** (9.85)
Tech × Year FE	Yes	Yes
Country × Year FE	Yes	Yes
Observations	18,673	12,581
No. of Countries	75	53
R-squared	0.94	0.94

Notes: This table presents the ordinary least square estimates for the effect of individualism, intellectual property rights and their interaction term on technology adoption. The numbers in parentheses are t-statistics and are based on robust standard errors clustered at the country level. ***, **, and * indicates that the coefficient is significant at the 1%, 5%, and 10% level, respectively. The dependent variable is the log transformed standardized technology adoption level (CHAT Dataset). Individualism is the individualism index (Hofstede et al., 2010). IPR is to the Intellectual Property Rights index (Ginarte and Park, 1997; Park, 2008). Column (1) excludes of the top and bottom 5% of the most and least individualistic countries. Column (2) excludes the top and bottom 15% of the most and least individualistic countries.

Table 1.A.6: Time varying impact of individualism

	(1)	(2)	(3)	(4)
Individualism	1.145*** (54.898)		0.690*** (30.019)	0.168*** (8.077)
IPR		0.455*** (43.653)	0.455*** (43.653)	0.455*** (43.653)
Individualism × IPR				0.522*** (26.522)
Constant	-2.971*** (-48.064)	-2.971*** (-48.064)	-2.971*** (-48.064)	-2.971*** (-48.064)
Individualism × Year	Yes	Yes	Yes	Yes
Tech × Year FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
R-squared	0.942	0.942	0.942	0.942
Observations	20782	20782	20782	20782

Notes: This table presents the ordinary least square estimates for the effect of individualism, intellectual property rights and their interaction term on technology adoption. The numbers in parentheses are t-statistics and are based on robust standard errors clustered at the country level. ***, **, and * indicates that the coefficient is significant at the 1%, 5%, and 10% level, respectively.

Table 1.A.7: Estimations using Patents Granted

	(1)	(2)	(3)	(4)
Dep. Var. = Log of patents granted per million population	WIPO		USPTO	
IPR	0.62** (2.11)	0.62** (2.08)	0.68* (1.75)	0.65** (1.72)
Individualism	0.66** (2.93)	0.65** (2.59)	0.75** (3.55)	0.99*** (4.46)
Individualism × IPR	0.66* (1.75)	0.67* (1.74)	0.77* (1.76)	0.64 (1.56)
Year FE	No	Yes	No	Yes
Observations	1,072	1,072	1,224	1,224
No. of Countries	68	68	74	74
R-squared	0.54	0.55	0.57	0.58

Notes: This table presents the ordinary least square estimates for the effect of individualism, intellectual property rights and their interaction on technology adoption. t-statistics within parentheses, based on robust standard errors clustered at the country level. ***, ** and * indicates significance at the 1%, 5% and 10% level, respectively. The dependent variable in columns (1) and (2) is the log transformed patents granted per million population from WIPO (2017) and USPTO (2017), respectively. Individualism is the individualism index (Source: Hofstede et al., 2010). IPR is to the Intellectual Property Rights index (Ginarte and Park, 1997; Park, 2008).

2. Can traditional farming practices explain attitudes towards scientific progress?

2.1. 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, 1991; 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., 2014). 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, 2019; 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 43 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; Moky, 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 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 2.1 introduces the topic and describes the paper's motivation. Section 2.2 sets out the conceptual framework this paper will use to discover any potential links between individualism and positive attitudes towards technology. Section 2.3 describes the estimation strategy, data sources, and validity checks the paper used for its crop measures. Section 2.4 presents the results of the baseline model, followed by descriptions of the robustness checks, used to verify results. Section 2.5 makes a more in-depth investigation of the channels that lie beneath the results. Section 2.6 presents and comments on the study's additional findings, before Section 2.7 makes the paper's conclusions. Finally, the two appendices present the paper's data sources and some supplementary analyses.

2.2. 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.

2.3. Data and Empirical Strategy

2.3.1. 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, whereas 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;

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

where $Tech.Attitude_{ijkt}$ 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 ¹⁴. 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 interview year-fixed effects (ν_t) to control for time variant differences within the survey period.

2.3.2. Data

This section gives a detailed explanation of the variables used. Overall, the baseline sample consisted of 41045 individuals from 46 countries, and covered 437 subnational regions. For detailed definitions of the variables and the data sources, please refer to Table 2.A.1 in Appendix A.

(i) 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 Appendix A for the correlation

¹⁴ 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.

between the first principal component and the seven individual questions.)

(ii) Individualism- and collectivism-enhancing crops

The study used eight crops to obtain separate measurements for 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 2.1 summarizes the available historical labor intensities, for a variety of crops. The U.S. Department of Agriculture (1922) reported the number of man-hours¹⁵, 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.

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 2.1 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,

¹⁵ A historically acceptable term in 1922.

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.

Table 2.1: Summary of crop specific labor intensities from different sources

	U.S. Dep. of Agriculture (1922)	Lenhart (1945)	Cooper et al. (1916)	Fouka and Schlaepfer (2017)	Pimentel (2009)
Crop	Man-labor hours, per acre	Man-week of labor, per acre	Labor hours, per acre	Labor shares from Prussian agri. data	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			12.2		
Hay	11.4				
Clover Hay	10.4				
Wheat	10.3		12.3	0.400	7.8
Winter wheat	9.7				
Mixed tame			12.3		
Hay	8.5				
Timothy Hay	8.1				
Clover seed	7.2		9.2		
Timothy seed	6.6		5.1		
Sorghum		0.0500			

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. Figure 2.1 shows the crop suitability of wheat, mapped over the GADM’s first-level administration districts within the United States. Figure 2.2 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.

Figure 2.1: Map of the suitability index of wheat, projected over the first-level administration districts, in the United States.

Figure 2.2: Map of the suitability index of wheat, averaged over the first-level administration districts, 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 100km²). Figure 1.a reflects the grid data projected over the first-level administrative districts taken from the GADM. Figure 2.2 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.

(iii) 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/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.

2.3.3. 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).

Table 2.2: 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** (2.296)	0.075*** (5.579)	0.062*** (5.175)	0.023* (1.792)	0.012 (1.029)	0.032*** (2.608)
COLL crops	-0.045*** (-3.261)	-0.108*** (-7.462)	-0.071*** (-5.445)	-0.024* (-1.777)	-0.023* (-1.672)	-0.047*** (-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.	51452	51452	51452	49003	48897	47087

*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 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

Columns (1)–(5) of Table 2.2 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 2.A.5 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.

2.4. Findings

2.4.1. Subnational Estimates- Baseline Results

Table 2.3 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 2.3 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.

2.4.2. Include Additional Historical and Contemporary Determinants

Table 2.4 shows the controls for a series of confounding factors, used to isolate the effect of historical farming's legacy on individual attitudes 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 1000BC, 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.

Table 2.3: Effect of individualism and collectivism enhancing crops on attitudes towards S&T

Dep. variable	(1) Q1	(2) Q2	(3) Q3	(4) Q4	(5) Q5	(6) Q6	(7) Q7	(8) PCA
IDV crops	0.024* (1.651)	0.044*** (2.984)	0.040*** (2.707)	0.001 (0.055)	0.025* (1.794)	0.046*** (3.218)	0.066*** (4.605)	0.053*** (3.735)
COLL crops	-0.040*** (-2.592)	-0.008 (-0.496)	-0.011 (-0.682)	-0.020 (-1.324)	-0.059*** (-3.934)	-0.059*** (-3.899)	-0.046*** (-2.978)	-0.035** (-2.329)
Age	-0.046* (-1.673)	-0.167*** (-5.969)	-0.160*** (-5.715)	-0.124*** (-4.507)	0.078*** (2.885)	0.095*** (3.403)	0.035 (1.249)	-0.162*** (-5.908)
Age squared	-0.027 (-1.011)	0.140*** (5.107)	0.144*** (5.251)	0.096*** (3.548)	-0.108*** (-4.028)	-0.104*** (-3.802)	-0.030 (-1.115)	0.123*** (4.556)
Marital status	-0.015*** (-2.851)	0.019*** (3.434)	0.020*** (3.657)	0.014*** (2.663)	-0.003 (-0.564)	-0.002 (-0.312)	0.017*** (3.132)	0.020*** (3.791)
Gender, male	0.021*** (4.383)	0.043*** (9.093)	0.021*** (4.376)	0.031*** (6.632)	0.013*** (2.766)	0.022*** (4.638)	0.036*** (7.679)	0.047*** (10.157)
landlockedness	0.232*** (11.117)	0.074*** (3.697)	0.213*** (11.082)	0.016 (0.765)	-0.042** (-2.229)	0.106*** (5.372)	0.342*** (16.699)	0.211*** (10.994)
Elevation	-0.026*** (-3.524)	-0.028*** (-3.997)	-0.028*** (-4.044)	0.021*** (2.864)	0.009 (1.198)	-0.030*** (-3.891)	-0.006 (-0.807)	-0.022*** (-3.395)
Distance to river	0.048*** (5.864)	0.005 (0.552)	0.003 (0.381)	-0.039*** (-4.461)	0.002 (0.298)	0.029*** (3.432)	0.001 (0.110)	0.000 (0.029)
Historical precipitation	0.040*** (3.850)	-0.027** (-2.534)	-0.031*** (-2.825)	-0.010 (-0.927)	-0.002 (-0.151)	-0.037*** (-3.659)	-0.052*** (-4.855)	-0.032*** (-3.113)
Historical temperature	0.010 (0.703)	0.070*** (4.609)	0.065*** (4.287)	0.044*** (3.068)	-0.061*** (-4.292)	-0.017 (-1.199)	0.150*** (9.980)	0.087*** (6.006)
Terrain roughness	0.013 (1.558)	0.036*** (4.503)	0.046*** (5.580)	0.030*** (3.948)	0.031*** (3.909)	0.007 (0.895)	-0.035*** (-4.241)	0.043*** (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	41045	41045	41045	41045	41045	41045	41045	41045

*Note: See Appendix A, Table 2.A.2 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 2010–2014. 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 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Results are consistent with clustered standard errors at the country level. Please refer to Table 2.A.6.*

Table 2.4: Effect of IDV and COLL crop measures on S&T attitudes after accounting for historical effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
IDV crops	0.118*** (12.360)	0.144*** (14.624)	0.067*** (5.524)	0.078*** (6.553)	0.122*** (12.096)	0.113*** (10.670)	0.125*** (11.558)	0.088*** (8.506)	0.139*** (14.125)	0.130*** (13.238)	0.127*** (12.604)
COLL crops	-0.122*** (-13.975)	-0.151*** (-16.511)	-0.059*** (-5.428)	-0.061*** (-5.752)	-0.120*** (-12.909)	-0.115*** (-12.262)	-0.117*** (-11.125)	-0.060*** (-5.840)	-0.141*** (-15.694)	-0.078*** (-7.997)	-0.138*** (-15.227)
Irrigation Potential 1900AD		-0.051*** (-8.609)									
Technology adoption 1500AD			0.270*** (17.941)								
(ln) population density 1500AD				0.035*** (2.714)							
Urbanization rate 1000BC				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)
Indi. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geo. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Continent FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	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
No of observations	41045	39358	30957	39649	40246	37745	40246	40246	40246	40246	39975

*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 2010–2014. The coefficients are standardized beta coefficients with t statistics in parentheses. Standard errors are robust and coefficients are significant at * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

Table 2.5: Effect of IDV and COLL crop measures on S&T attitudes after accounting for contemporary effects

	(1)	(2)	(3)	(4)
IDV crops	0.125*** (9.742)	0.060*** (5.923)	0.169*** (15.840)	0.070*** (6.855)
COLL crops	-0.115*** (-10.253)	-0.048*** (-4.984)	-0.165*** (-16.463)	-0.047*** (-4.558)
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)
Area equipped for irrigation				-0.205*** (-19.900)
Indi. controls	Yes	Yes	Yes	Yes
Geo. controls	Yes	Yes	Yes	Yes
Continent FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R square	0.059	0.076	0.071	0.090
No of observations	29538	39975	37034	37108

*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 2010–2014. The coefficients are standardized beta coefficients with t statistics in parentheses. Standard errors are robust and coefficients are significant at * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

Next, I controlled for a series of contemporary conditions that may have affected modern-day attitudes towards technology. Column (1) of Table 2.5 controls for current technological adoption rates, whereas Column (2) includes a polity IV score as a measurement of current political development. Column (3) 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 (4) 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.

2.4.3. 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 rice¹⁶. Next, I regressed the most individualistic crop (wheat) against the most collectivist crop (potatoes) on individual attitudes towards technology. Column (1), in Table 2.6, 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.

¹⁶ 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 2.6: 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	40942	47848	47848	47848	47848	47848

*Note: Column (1) shows the results of the study's analysis of 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 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

Table 2.7: 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*** (6.979)	0.106** (3.195)	0.050 (1.284)	0.086** (2.681)	-0.057* (-2.037)	0.055 (1.427)	0.231*** (4.272)	0.873** (3.438)
COLL crops (father's country of origin)	-0.351*** (-7.213)	-0.162** (-3.289)	-0.079 (-1.342)	-0.139** (-2.843)	0.077 (1.837)	-0.082 (-1.423)	-0.335*** (-4.105)	-1.358** (-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*** (4.578)	0.007 (1.111)	-0.003 (-0.215)	0.034** (2.733)	0.030 (1.723)	0.096** (3.456)	0.077** (3.912)	0.339** (3.383)
COLL crops (mother's country of origin)	-0.112*** (-6.657)	-0.014 (-1.306)	0.004 (0.234)	-0.052** (-3.017)	-0.057* (-2.039)	-0.148** (-3.596)	-0.130*** (-4.310)	-0.580*** (-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 2.A.2 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 2010–2014. 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 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

2.5. Examining the Underlying Channels

2.5.1. 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 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 2.7 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.

2.5.2. 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 decline¹⁷. 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, and bird scaring, threshing, and drying the paddy harvest. Therefore, women's 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 2.8 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

¹⁷ For example, in 1964, 95% of rural farmers in China were women (Huang, 1993).

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.

Table 2.8: Heterogeneous effects by gender

	Heterogeneous effects by gender		
	(1) Male	(2) Female	(3) Difference in coefficients
IDV crops	0.0043*** (3.8290)	0.0020* (1.9027)	115%
COLL crops	-0.0059*** (-4.2514)	-0.0047*** (-3.4965)	25%
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	19780	20240	

*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 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

2.6. 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. Figure 2.3 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 2.9 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.

Figure 2.3: Relationship between attitudes towards technology and economic development, measured by income per capita in 2015, and night light intensity per capita in 2010.

Table 2.9: 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* (1.713)	0.297* (1.822)	0.304** (2.462)
Landlockedness	-0.120 (-1.359)	-0.284** (-2.601)	-0.174 (-1.388)
Mean elevation	-0.116 (-0.752)	-0.099 (-0.577)	0.235 (1.219)
Distance to river	0.118 (0.854)	0.087 (0.713)	0.104 (0.725)
Current precipitation	0.220 (1.419)	0.283 (1.440)	0.426** (2.060)
Current temperature	-0.283** (-2.089)	-0.437*** (-2.953)	-0.477*** (-3.421)
Terrain roughness	-0.092 (-0.908)	-0.226 (-1.351)	-0.321** (-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 2017a. 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 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

2.7. 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, I find that deep rooted traditions lead to various cultural formations, and they have different implications on economic outcomes. 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. On the practical side, decision makers must use a spectrum of policy tools to carefully emphasize modern technology. For example, collectivist cultures can expand the role of technology in schools to encourage pro-technology attitudes.

2.8. Appendix A

Table 2.A.1: 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
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
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
[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
Latitude	The absolute value of the latitude of each first level administrative district.	The G-ECON Project
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
Mean precipitation	The average, annual precipitation in a first-level administrative district, for the period 1961–1990 (in mm).	FAO GAEZ

Variable	Description	Source
[A] Key variables		
Elevation	The mean elevation of a first-level administrative district for a country that is above sea level (in km).	The G-ECON Project
Terrain ruggedness	An index that measures small-scale terrain irregularities in each first-level administrative district of country.	The G-ECON Project
Mean temperature	The average annual temperature of a first-level administrative district of a country over the period 1961–1990 (in Celsius).	FAO GAEZ
[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
Gender	A dummy variable that takes the value 1 if the individual is male or 0, otherwise.	World Value Survey
Marital Status	A dummy variable that takes the value 1 if the individual is married or 0, otherwise.	World Value Survey
[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 1000BC	This is the historical urbanization rate in 1000BC constructed at the country-level.	Peregrine (2003)

Variable	Description	Source
[A] Key variables		
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
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).		

Variable	Description	Source
[A] Key variables		
Population density	Population density was calculated using population (in 10000 persons) and land area (sqkm) for 22 provinces within China.	NBS China
Income per capita	Per capita regional income (yuan/person).	NBS China
Irrigation	The total irrigated land, in 2012, at the provincial level.	NBS China
Education-primary	Students per 100000 populations, in primary education.	NBS China
Education-secondary	Students per 100000 populations, in secondary education.	NBS China
Gini coefficient	Gini coefficient in 2012.	NBS China
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 2.A.2: 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 2.A.3: 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	1,108	150.52	173.97	0	895.74
Distance to river	1,108	441022.9	469345.5	0	2564713
Mean precipitation	3,320	1119.79	739.05	1	4530
Mean temperature	3,320	18.01	8.37	-23.38	29.97
Terrain roughness	1,108	0.17	0.21	0	1.13

Table 2.A.4: 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
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 2.A.5: Strength of crop measures capturing individualism and collectivism cultures at the country level

	(1) Ang (2019)	(2) Suh et al. (1998)	(3) Hofstede et al. (2010)	(4) Tang and Koveos (2008)
IDV crops	0.766*** (2.948)	0.790** (2.298)	0.530** (2.454)	0.766*** (2.948)
COLL crops	-0.511** (-2.131)	-0.524* (-1.958)	-0.123 (-0.630)	-0.511** (-2.131)
Landlocked	-0.048 (-0.408)	0.073 (0.412)	0.074 (0.759)	-0.048 (-0.408)
Mean elevation	-0.283* (-1.959)	0.105 (0.481)	-0.062 (-0.453)	-0.283* (-1.959)
Terrain roughness	-0.158 (-1.318)	-0.264* (-1.723)	-0.087 (-0.697)	-0.158 (-1.318)
Historical precipitation	0.411** (2.225)	0.028 (0.159)	-0.040 (-0.272)	0.411** (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 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.A.6: Robustness to clustered standard errors at the subnational level

Dep. variable	(1) Q1	(2) Q2	(3) Q3	(4) Q4	(5) Q5	(6) Q6	(7) Q7	(8) PCA
IDV crops	0.152*** (3.169)	0.127*** (3.000)	0.073 (1.525)	0.033 (0.618)	0.100* (1.885)	0.066 (1.246)	0.130** (2.412)	0.144** (2.665)
COLL crops	-0.215*** (-4.352)	-0.129*** (-2.825)	-0.049 (-0.904)	-0.068 (-1.318)	-0.195*** (-4.089)	-0.114** (-2.574)	-0.097* (-1.681)	- (-2.810)
Age	-0.036 (-1.052)	-0.133*** (-3.124)	-0.136*** (-2.783)	-0.087** (-2.140)	0.065* (1.728)	0.082* (1.821)	0.032 (0.971)	0.128*** (-2.782)
Age squared	-0.031 (-0.948)	0.095** (2.300)	0.109** (2.321)	0.051 (1.388)	-0.073** (-2.082)	-0.073 (-1.595)	-0.020 (-0.726)	0.082* (1.902)
Marital status	-0.008 (-0.664)	0.018* (1.947)	0.022** (2.334)	0.020** (2.079)	0.002 (0.238)	0.004 (0.469)	0.029** (2.535)	0.026** (2.340)
Gender, male	0.028*** (3.772)	0.042*** (5.085)	0.019*** (2.731)	0.028*** (3.748)	0.016 (1.654)	0.023*** (3.153)	0.035*** (5.888)	0.046*** (4.900)
landlockedness	0.103*** (2.724)	0.072* (1.873)	0.049 (1.232)	0.040 (0.855)	0.003 (0.080)	0.063* (1.958)	0.053 (1.509)	0.090* (1.930)
Elevation	-0.040* (-1.972)	-0.045* (-1.899)	-0.044* (-1.857)	0.035 (1.245)	-0.013 (-0.587)	-0.016 (-0.714)	-0.034 (-1.267)	-0.038 (-1.468)
Distance to river	0.002 (0.054)	-0.006 (-0.241)	-0.009 (-0.286)	-0.042 (-1.407)	-0.013 (-0.306)	-0.012 (-0.399)	0.045* (1.840)	-0.015 (-0.476)
Historical precip.	0.073* (1.879)	-0.075** (-2.152)	-0.091** (-2.483)	-0.044 (-1.376)	0.007 (0.173)	0.014 (0.477)	-0.045 (-1.528)	-0.076* (-1.816)
Historical temperature	-0.077* (-1.766)	0.017 (0.501)	-0.036 (-0.879)	-0.079* (-1.752)	-0.144*** (-3.069)	-0.123*** (-3.387)	0.163*** (3.747)	-0.040 (-0.815)
Terrain roughness	-0.094*** (-4.459)	-0.035 (-1.333)	0.003 (0.110)	-0.043 (-1.354)	-0.140*** (-4.971)	-0.059** (-2.407)	-0.015 (-0.503)	-0.056* (-1.694)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R square	0.038	0.027	0.024	0.033	0.050	0.040	0.030	0.048
No of observations	41045	41045	41045	41045	41045	41045	41045	41045

*Note: See Appendix A, Table 2.A.2 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 2010–2014. 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 clustered at the country level. Coefficients are significant at * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. results weaken when country fixed effects are included together with clustered standard errors and hence, I acknowledge this as a limitation to the study.*

2.9. Appendix B

2.9.1. 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 2.B.1 and 2.B.2, show the distribution of individualism/collectivism-enhancing crop measures across 31 provinces in China. Table 2.B.1 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.

2.9.2. Country Level Estimates

In addition to the subnational estimates, I tested the consistency of the study's results at the cross-country level. Table 2.B.2 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 OAD, 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.

Figure 2.B.1: Distribution of the individualism-enhancing crops across China

Figure 2.B.2: Distribution of the collectivism-enhancing crops across China

Table 2.B.1: OLS estimates for China

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
IDV crops	0.100*** (5.322)	0.266*** (17.294)	0.489*** (18.896)	0.263*** (12.865)	0.266*** (17.072)	0.265*** (15.578)	0.318*** (2.895)	0.286*** (3.221)	2.843*** (22.386)	3.948*** (38.920)
COLL crops	-0.106*** (-6.738)	-0.656*** (-27.157)	-0.741*** (-11.502)	-0.654*** (-23.845)	-0.657*** (-27.461)	-0.658*** (-27.430)	-0.708*** (-11.096)	-0.674*** (-8.606)	-2.885*** (-23.351)	-11.994*** (-34.672)
Cotton suitability			-0.056 (-1.265)							14.500*** (33.488)
Population density				0.004 (0.227)						9.993*** (34.450)
Income per capita					0.001 (0.227)					-11.251*** (-34.964)
Irrigated Land						-0.006 (-0.227)				-5.314*** (-32.059)
Disease (1408–1911)							0.019 (0.486)			-0.271*** (-31.754)
Gini coefficient								0.004 (0.227)		1.387*** (39.612)
Students in primary edu.									0.365*** (17.560)	-1.674*** (-43.411)
Students in secondary edu.									-1.952*** (-23.723)	-7.277*** (-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 2.A.2 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 2010–2014. 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 2.B.2: Country level estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
IDV crops	0.496* (1.814)	0.550** (2.109)	0.529* (1.764)	0.505* (1.884)	0.514* (1.766)	0.485* (1.725)	0.545** (2.118)	0.717** (2.505)	0.516* (1.861)	0.502* (1.789)	0.461* (1.843)
COLL crops	-0.699*** (-2.884)	-0.746*** (-3.056)	-0.941*** (-3.238)	-0.691*** (-2.831)	-0.719*** (-2.864)	-0.705*** (-2.817)	-0.729*** (-3.078)	-0.911*** (-3.467)	-0.738*** (-2.889)	-0.714*** (-2.909)	-0.608** (-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 2010–2014. 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 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

3.Trusting in Cultural Similarities When Sharing Knowledge

3.1 Introduction

Collaborative research and innovation have become increasingly important with global connectivity, and inventors and researchers from various socio-economic and cultural backgrounds are coming together to innovate and create novel ideas (Powell et al., 1996; Ahuja, 2000; Lo and Li, 2018). It is crucial to maintaining competitiveness, produce cutting-edge technologies, and research. But what drives people to jointly innovate or create when risks of exploitation and free-riding exist? Do cultural similarities engender collaborative innovation through mutual trust and perhaps other forms of social preferences? This paper addresses these questions by uncovering the black box of how cultural similarities affect intangible knowledge sharing decisions.

Collaborative efforts require common goals for people to come together to share knowledge. Collaborators engage in common practices to signal their commitment to a common cause (von Krogh et al., 2012) and share the risks and rewards (Abhari et al., 2019). Institutional provisions and economic efficiencies can promote strategic alliances of such nature, and partnerships could emerge out of cultural similarities. For instance, cultural similarities signal shared values, norms, customs, and social behaviors, and these characteristics could spill over to encourage collaborations of above nature. The underlying mechanism is that cultural similarities induce mutual trust via ingroup biases. Ingroup bias is the tendency to favor one's group or group members over others (Sumner, 1906). Social identity theories predict that individual behavior of identifying themselves as part of social categories leads to identity-based preferences and ingroup biases (Sherif et al., 1961; Tajfel and Turner, 1979; Landa, 1994; Akerlof and Kranton, 2000). Since people derive emotional value, pride, and self-esteem through group memberships, it emotionally connects and bonds people from similar cultural backgrounds leading to ingroup biases (Tajfel and Turner, 1979). Therefore, group identification is sufficient to induce mutual trust among members (Tajfel and Turner, 1979). Nonetheless, the degree of group identification raises ingroup biases by signaling one's willingness to cooperate with group members (Eckel and Grossman, 2005). For example,

costly rituals discourage free-riders by signaling one's commitment and devotion to the group, thereby raising mutual trust among group members (Ruffle and Sosis, 2007).

The experimental literature has already established that religious similarities lead to cooperation through mutual trust generated by ingroup biases (Ruffle and Sosis, 2007; Tan and Vogel, 2008; Soler, 2011; Levy and Razin, 2012; Chuah et al., 2016). Similarly, empirical literature shows that cultural similarities positively affect cooperative economic transactions at the national level, e.g., bilateral trade, foreign direct investment allocations, merge and acquisitions decisions, and strategic alliances (Rauch and Trindade, 2002; Guo, 2004; Helble, 2007; Nielsen, 2007; Guiso et al., 2009; Tabellini, 2010; Hergueux, 2011; Egger and Lassmann, 2012; Falck et al., 2012; Lameli et al., 2015; Ahern et al., 2015;). However, further research is required to examine whether cultural similarities promote cooperation when intangible knowledge is shared. Second, the literature needs to explore under what institutional conditions cultural similarities foster collaborative innovation. For instance, if cultural similarities encourage knowledge sharing via mutual trust, it should be prominent in environments with weak rule of law. Third, the literature does not investigate whether sharing in different contexts, such as prosocial behaviors in wealth sharing are predictive of intangible knowledge sharing decisions. Therefore, we aim to fill these gaps in the literature, both empirically and experimentally.

We first motivate our study by providing empirical evidence to support that cultural similarities increase bilateral innovation. Using bilateral patent collaborations, we find that religious similarities promote collaborative innovation between countries. We also find that the positive effects of religious similarity have a more significant impact on societies with weak Intellectual Property Rights (IPR) protection where trust is more required for fostering cooperation than in societies with strict IPR protection, where there is strong rule of law. However, our empirical evidence of cultural similarity is limited to the dimension of religion, and the data is unable to tell us the underlying mechanism of these results. For instance, whether it is due to mutual trust, reduced transaction costs, or expedited information flows.

Additionally, aggregate country-level patent data suffer from micro-level insights—for example, cultural identities and heterogeneous demographic distributions of inventors within countries are unavailable. The standard approach of using aggregate distributions of national cultures as a proxy for

cultural similarity can obscure the actual distribution of cultures within the technology innovation landscape. Furthermore, collaborative innovations initiated by public or private research entities may not be driven by cultural factors. While we acknowledge the natural limitations of cross-country analyses, our empirical findings provide preliminary evidence for the positive effect of cultural similarity on collaborative technology innovation.

Motivated by empirical evidence, we adopt an experimental approach to shed behavioral insight on how cultural identities affect an individual's strategic motives to cooperate or contribute to a team's innovative effort under varying rules of law. In the experiment, we model and generate synthetic lab cultures. There are several advantages to this approach. First, culture is multifaceted. Instead of priming on natural identities such as religion, ethnicity, and language (Tan and Vogel, 2008; Chuah et al., 2016), we induce cultural identity along four dimensions: *beliefs*, *fate*, *rituals*, and *experiences*. Second, we avoid importing certain homegrown norms, stereotypes, and expectations attached to naturally occurring identities. Third, laboratory experiments provide cleaner environments for testing our hypotheses by separating and isolating various psychological factors and behaviors that affect individuals' strategic motives to cooperate during the identity formation process. Fourth, incentives are comparable across interactions, as opposed to patent data, where they differ according to the value of inventions. Fifth, unlike in the cross-country analyses, we can control for exogenous influences from the external environment.

To model synthetic lab cultures, it is vital to understand the core characteristics of cultures. According to Fiske (2002, p. 85), cultures are collections of "practices, competencies, ideas, schemas, symbols, values, norms, institutions, goals, constitutive rules, artifacts, and modifications of the physical environment." In the literature, these features categorize into four dimensions (Stark and Glock, 1968; De Jong et al., 1976; Corazzini and Sugden, 2010; Coyne and Mathers, 2011; Levy and Razin, 2012). The first dimension is *common beliefs*. It is the closeness of one's beliefs to the ideologies of their culture. Survival of cultures depends on the cohesiveness and individual conformity to cultural beliefs, values, and norms (Levy and Razin, 2012). Therefore, it is the foundation of cultural identity. The second dimension is *common fate*. Cultures instill faith in common destinies where members expect to be either rewarded or punished according to their cultural obedience. Trusting a common fate is found to increase the cultural identity of group members (Corazzini and Sugden, 2010). For example, people from religions that believe in an afterlife or rebirth

may feel somewhat connected in contrast to those who come from religions that deny rebirth.

The third dimension is *ritual participation*. According to Coyne and Mathers (2011), rituals are “predictable and regular observance of some act or procedure, which has a symbolic element resulting in the inculcation or reinforcement of shared values and beliefs.” Therefore, rituals are meaningful, repetitive, and synchronous acts that enhance individual beliefs and values.¹⁸ Hence, rituals naturally intertwine with cultural beliefs. Performing ritualistic acts should indirectly contribute to the survival of their cultures. For instance, rituals are crucial to transmit traditions and customs from one generation to another. Therefore, rituals have social implications. Another salient feature of ritual participation is they are voluntary and costly commitments with no financial benefits (Levy and Razin, 2012).¹⁹ Additionally, rituals must be non-egoistic, cohesive, and affirmative. The fourth dimension is *common experience*, where individuals attach value to their cultural engagement by adhering to their cultural beliefs and performing costly rituals (Tan, 2006). This is known as *cultural experience*. Therefore, *beliefs, fate, rituals, and experience* are the cornerstones of our synthetic cultures.

Prior studies have used common beliefs and common fate manipulations to induce mutual trust via ingroup biases in cooperative games (Brewer and Kramer, 1986; Bacharach, 2006; Tan and Zizzo, 2008; Chen and Li, 2009; Corazzini and Sugden, 2010;). For instance, Corazzini and Sugden (2010) observe strong reciprocity and high contribution among groups exposed to a common fate relative to those with either individual fate or rival fates. Cooperation in prosocial games varies according to group salience, group formation, the degree of common fate (for a survey see Tan and Zizzo, 2008).

Similarly, ritual participation reinforces social identity, social organization, and cooperation (Bell, 1992; Bell, 1997; Berman, 2000; Chwe, 2003; Ruffle and Sosis, 2007; Coyne and Mathers, 2011; Levy and Razin, 2012). Ruffle and Sosis (2007) study on religious kibbutzim show that rituals act as a screening mechanism to overcome free-riding problems. For instance, the costs involved in producing signals (e.g., time, effort, and resources) prevent free-riders from falsely advertising themselves as trustworthy and ensure that only

¹⁸ Rituals could be intrinsically or extrinsically motivated. For instance, some could attend church to achieve religious goals to benefit themselves (intrinsic motivations), while others' decision to attend church may be motivated by family members (extrinsic motivations) (Allport and Ross, 1967).

¹⁹ Rituals are costly commitments since individuals put in time, effort (physical or cognitive), and resources (e.g., money spent on organizing ritual ceremonies) to perform them.

those who are committed and devoted will benefit from group membership (Irons, 2001). Therefore, costly rituals are “hard-to-fake” signals of one’s commitment to a group (Irons, 2001; Ruffle and Sosis, 2007; Soler, 2011). Rituals can also overcome problems of information asymmetries (Coyne and Mathers, 2011). Landa (1994) observes that gift-exchanging rituals among trading partners act as a signal for commitment, resulting in lower transaction costs and increased cooperation between traders. Likewise, Leeson (2006) explores how cooperation between heterogeneous agents improves when outsiders engage in shared customs and rituals as the ingroup members to signal credibility and trustworthiness. However, prior studies use existing customs and ritual practices to explain the effects of social identity on cooperation and social cohesion in natural settings. Only a few studies make a modest effort to elicit rituals in a laboratory setting. For example, Norton and Gino (2014) and Brooks et al. (2016) model rituals through a sequence of unrelated symbolic acts with no real meaning or instrumental purpose to monitor emotional outcomes. However, these manipulations fail to capture the essential characteristics of ritual participation described above.

This paper deviates from past literature in a few ways. Firstly, unlike prior research, we jointly model *beliefs*, *fate*, *rituals*, and *experiences* in one framework to manipulate individuals’ social identities. One of the main contributions of our experimental approach is to model rituals using a novel Social Interaction Game (SIG) to capture important characteristics of ritual participation discussed above. Secondly, we test whether these social manipulations explain social value orientations towards trust, trustworthiness, altruism, inequality aversion, and tolerance. Thirdly, we manipulate social identities to observe cooperative behavior when intangible knowledge is shared. Prior studies have found that group identity leads to more wealth-sharing among ingroup members based on mutual trust in public goods games (Eckel and Grossman, 2005; Tan and Bolle, 2007; Corazzini and Sugden, 2010; Charness et al. 2014), trust games (Tan and Zizzo, 2008; Hargreaves Heap and Zizzo, 2009), prisoners’ dilemma, stag-hunt games (Charness et al., 2007), and bargaining games (McLeish and Oxoby, 2007).

However, this paper explicitly focuses on the cooperative behavior of individuals when intangible knowledge is shared. Therefore, the main contribution is to model intangible knowledge sharing with induced value, where incentives central to knowledge sharing are varied systematically. We extend Gächter et al. (2010) game-theoretic approach to model knowledge

sharing in private-collective innovation by observing how individual knowledge sharing decisions vary when inventors are provided with additional information on the social identities of their partners.²⁰ We use exclusive appropriation in Gächter et al. (2010) to manipulate IPR protection in the knowledge sharing environment to identify the interplay of cultural similarity and IPR protection on individuals' knowledge sharing decisions. Lastly, we investigate the role of social preferences in transmitting ingroup biases generated by various social identity manipulations. I.e., to test whether prosocial behaviors in wealth sharing have any effects on intangible knowledge sharing decisions.

Our experimental results show that ingroup biases observed in the knowledge sharing games largely depends on the individual performance in the social interaction games used to elicit ritual participation. Therefore, the novel social interaction game is crucial to signal one's devotion and commitment to the group, thereby generating ingroup biases through mutual trust. However, ritual participation negatively affected ingroup favoritism on those who did not perform well in the social interaction game. Nonconformity to repetitive group tasks led to them exhibiting weak group effects. Additionally, experimental results confirm that cultural similarity increases its importance in the presence of low IPR protection. Therefore, the interaction between cultural similarity and IPR protection has a negative effect on knowledge sharing. The results also show that prosocial behaviors are predictive of knowledge sharing decisions. For instance, social preferences for trust and altruism mediates the positive impact of cultural similarity on knowledge sharing behavior.

Overall, the paper organizes as follows. Section 3.2 presents the literature on modeling culture using core dimensions, beliefs, fate, rituals, and experiences. Section 3.3 offers the empirical motivations of the study. Section

²⁰ Gächter et al. (2010) specify three models that incentivize innovation; (1) private-investment model; (2) collective action model; and (3) private-collective innovation model. Their knowledge sharing game is largely built on the private-collective innovation model. It assumes that inventors contribute voluntarily and privately to collaborative innovation, and it creates community-related incentives. For example, open-source software (OSS) communities operate as "gift economies" (Gächter et al., 2010). When software developers receive knowledge there is a strong social obligation to reciprocate with the same. However, it entails opportunity cost of giving up exclusivity rights. Therefore, in the absence of any incentive structure or formal contracts, inventors share knowledge based on social preferences for fairness, efficiency, and reciprocity (Gächter et al., 2010). However, in the real world there is a possibility that inventors hide behind this "veil" and innovations never materialize. We expect collaboration to lead innovation with some probability p . Therefore, when we employ Gächter et al. (2010) knowledge sharing game to model collaborative innovation, we assume that there is a perfect correlation between collaboration and innovation by assuming the risk factor to be zero. However, it is possible to vary the observability of collaboration and test the probability that an innovation is successful. We believe this would be an interesting direction for future research.

3.4 sets out the experimental design, while section 3.5 presents the results. Section 3.6 concludes.

3.2 Modelling culture

Religion, ethnicity, language, individualism-collectivism, nationality, socioeconomic status (class, taste), education (meritocracy vs. aristocracy), and geography (regions, political segregations) symbolize various forms of culture. People often use them to identify themselves into different social groups. Modeling cultures through components that cover various cultural institutions are important to disentangle the causes and effects of cultural similarities, in general. Therefore, this section explores the multidimensional nature of cultures. Kroeber and Kluckhohn (1952) categorize culture into a broad set of categories based on heritage, tradition, common practices, psychological and genetic differences. Despite the many classifications, there is a consensus that culture has shared elements, and cultural formations are determined by repeated interactions with humans and the environment transmitted across time and generations (Triandis, 2007; Fiske, 2002; Cohen, 2009).

We first explore the multidimensionality of religions and ethnicity and subsequently examine other forms of synthetically categorized cultures like individualism-collectivism. With the acculturation of religious values and practices throughout history, religions cause cultural formations. The literature considers religious *beliefs, fate, rituals, experience, and knowledge* as core dimensions of religions (Goldsen, 1960; Marx, 1967; Stark and Glock, 1968; King and Hunt, 1972). Religious beliefs capture the closeness of individual beliefs to religions' philosophical constructs (Tan, 2006). For example, it captures beliefs on the existence of a divine being, the role and actions required to fulfill the divines' will. Religious fate captures individuals' views of death, afterlife, and spirituality. The ritual dimension captures individual commitment and degree of participation in religious activities such as church attendance, reciting prayers, reading religious doctrine, giving tithes. Since individuals need to participate and allocate time, effort, and resources to engage and observe religious rituals, it is costly. Next, religious experience captures the extent to which individuals encounter religious context. For instance, individuals may feel spiritually connected and find salvation in a divine-being (Tan, 2006) or experience enlightenment. Lastly, the knowledge dimension captures individual knowledge about biblical and theological personalities, history, and the polity of

different religious doctrines (De Jong et al., 1976). Overall, the effects of religion on social preferences (Tan, 2006; Tan and Vogel, 2008), discrimination (Chuah et al., 2016), and cooperation (Ruffle and Sosis, 2007) have been studied experimentally along these dimensions.

Next, we try to uncover the core dimensions of ethnic identity. Isajiw (1993) finds ethnicity to be bifold. It is viewed from both the collective (ethnic group) and individual (ethnic identity) perspectives. At the collective level, ethnic groups refer to groups of people sharing the same cultural values and norms or descendants of such people who do not practice the same culture but acknowledge ancestral links (Isajiw, 1993). Since we attempt to create cultures that reflect core values of ethnicity at the individual level, let us focus more on the core characteristics of *ethnic identity*. Ethnic identity is a psychological phenomenon of locating oneself into social systems. The internal aspect of identifying oneself into social systems relies on images, ideas, attitudes, and feelings. Isajiw (1993) identifies three critical internal aspects of ethnic identity. First is the *Cognitive* aspect. It is the self-image and the image of one's group based on heritage, historical events, personalities, legacies, and values. The second is the *Moral* aspect. It is the feeling of obligation towards the group, and lastly, the *Affective* aspect is known as the feelings of attachment towards the group in terms of security, sympathy, and associative preference for inward group members. While it is difficult to connect these internal aspects to the core dimensions discussed above, we can broadly consider the internal *cognitive* aspect to resemble "ethnic knowledge".

The internal *moral* aspect is one's commitment or obligation to uphold and propagate traditions inherent to the group. Participation in ethnic networks, institutional organizations, functions, and ceremonies are crucial to preserve and transmit ethnic traditions from one generation to another. Other moral obligations include abiding by ethnic rules such as avoiding inter-ethnic marriages, conforming to specific dress codes and dietary patterns. Hence, moral obligations and commitments resemble *ethnic rituals*. According to Isajiw (1993), the internal *affective* aspect refers to one's attachment to the group. These feelings could manifest as finding security, sympathy, or a sense of belonging and, hence, classified as *ethnic experiences*. Besides, ethnic groups have certain ideologies regarding collective and individual action. For example, Hmong (a hill tribe living in Thailand) beliefs and traditions are deeply tied to animist rites and shamanism and rely on spirits, sorcery, and magic (Srithia et

al., 2012). Hence, we consider *ethnic beliefs* to be another important dimension of ethnic identity.

Next, the concept of individualism and collectivism has gained special attention in recent years. It is identified as one of the key cultural variables to explain technological differences between the East and the West (Talhelm et al., 2014; Gorodnichenko and Roland, 2017). Many studies find Western cultures to be individualistic and Eastern cultures to be collectivist. The psychological phenomenon behind individualism emphasizes and believes in “self” as independent by celebrating individual autonomy, preference, and desires (Snibbe and Markus, 2005; Kitayama et al., 2006; Gorodnichenko and Roland, 2017). Conversely, collectivist cultures attach value to groups emphasized by traditions, conformity, hierarchy, interdependence, and obedience (Triandis, 1995; Brewer and Chen, 2007). Hence, the division between individualism and collectivism is largely driven by individual beliefs and attitudes towards independence, autonomy, noncompliance against interdependence, conformity, and obedience. Unlike religion and ethnicity, individualism-collectivism has no ritualistic dimension. The cultural mandate on individualism enables individuals to express and pursue personal goals, maintain self-esteem, encourage risk-taking, and engage in creative and non-routine challenges. In contrast, collectivist cultures prefer to fit-in (Kitayama et al., 2009). Hence, we identify experience to be an important dimension of individualism-collectivism cultures.

Apart from religion and ethnicity (identity-based cultures), and individualism-collectivism (category-based cultures), a broad range of cultures fall into these core dimensions. Table 3.A.1 in Appendix A briefly elaborates how education, language, social status, political, national, and geographic identities resemble core characteristics discussed above. We can broadly define culture as a combination of certain *beliefs, fate, rituals, experiences, and knowledge*, and various cultures show different facets of these dimensions.

3.3 Empirical motivation

This section aims to find empirical evidence for the relationship between culture, IPR, and technology innovation. While we acknowledge that culture has many forms, studying all of them within the scope of this section is infeasible. Therefore, our empirical motivation limits to studying the impact of religious similarity, IPR, and their interaction on collaborative innovation. Religion plays

an important role in uplifting individual moral values and behaviors. Religious beliefs prevent individual temptation to free ride in fear of disapproval. Atkinson and Bourrat (2011) finds that beliefs in supernatural monitoring and punishment in their afterlife discourages individuals from violating establish moral values and norms and thereby facilitate interpersonal cooperation. Furthermore, religious participation in costly rituals is an “hard to fake” sign of individual commitment and act as a screening mechanism to overcome free-rider problems (Irons, 2001; Ruffle and Sosis, 2007). Therefore, religious similarities can signal common values, norms, practices and induce cooperative behavior. Therefore, it is well suited as a proxy for cultural similarity.

We use bilateral patent applications as a measure of collaborative innovation. OECD provides data on international cooperation in patents (i.e., patents with foreign co-inventors) using patent applications filed under the Patent Cooperation Treaty (PCT) for technology domains such as information and communication technologies, nanotechnology, biotechnology, and environment-related technologies. OECD patent data originates from the Worldwide Patent Statistical Database (PATSTAT) created by the European Patent Office (EPO). We use patent applications filed under the PCT between 2000 and 2016 (the latest year available). A patent application with international collaboration is found by considering all possible country pairs with inventors belonging to two or more different countries. For example, consider a patent application with inventors belonging to United States (USA), United Kingdom (GBR), and Canada (CAN). OECD creates distinct bilateral relationships by considering all possible country pairs. For instance, a unit count is assigned to all possible country pairs USA-GBR, USA-CAN, and GBR-CAN for the given patent application. Bilateral patent collaborations are found by aggregating patent applications for all country pairs between 2000 and 2016.²¹ Overall, there are 100 countries and 2992 country pairs in the baseline sample. Unlike trade or FDI stocks, we assume patent collaboration between, for instance, USA-GBR, to be the same as patent collaboration between GBR-USA.

Since the dependent variable considers all possible country pairs, the dataset is left-skewed, with most country pairs having zero patent collaboration. Hence, using ordinary least square estimation with log-linearized dependent variable is challenging, as zero patent collaborations will be excluded causing

²¹ The fraction of religious adherents belonging to each religious denominator move slowly across time (at least within the 15 years considered in the study), and hence, we do not use a panel framework in the analysis.

selection biases.²² Therefore, we use Poisson pseudo-maximum likelihood estimation in our gravity model.

The religious similarity variable is constructed using the religious affiliation data provided by McCleary and Barro (2006). We define *religious similarity* as the probability of randomly chosen country pair sharing the same religions (Helble, 2007; Guiso et al., 2009; Hergueux, 2011). That is, the product of r_i and r_j summed over all religions ($\sum_r r_i r_j$). r_i and r_j are the fraction of the population belonging to religion r in country i and country j , respectively. r refers to Catholic, Protestant, Jewish, Muslim, Hindus, Buddhist, and Orthodox religions. Based on the above classifications, the religious similarity between Turkey and Iraq is 0.93, while it is 0.005 between Spain and Iran. Therefore, it correctly captures the religious similarities between different countries. Data on IPR is from the Ginarte and Park (1997) database. In the gravity model, we use combined IPR levels in both countries.

We also introduce country fixed effects and some standard gravity control variables to the model. First is the *geographic distance* between two countries. Based on proximity advantages, the cost of knowledge transmission and information sharing decrease if two countries are closely situated. Hence, collaborative innovation should decrease with distance. On the same note, contiguity also plays a significant role. *Contiguity* is a dummy variable that takes the value one if two countries share a common border. It is important to control for contiguity since transportation costs related to technology diffusion could considerably lower if two countries share a common border. Lastly, the model controls for *common language* (a variable that takes a value one if a common language is spoken by at least 9% of the population) and *colonial relationship* (a dummy variable if the two countries have ever shared a similar colonial past). Data on geographical distance, contiguity, common language, and colonial relationship are from CEPII database.

Table 3.1 presents the results of the gravity model. Column (1) consists of only standard gravity variables. Logs of distance, common language, colonial relationship, and contiguity appear significant with all variables correctly signed. Column (2) introduces religious similarity. A significant and positive coefficient indicates that religious similarity promotes bilateral technology

²² Some authors bypass this issue by adding small fixed quantities before taking the log transformation (E.g.: $\ln(\delta + patents)$ where δ is a small quantity between 0 and 1. Nevertheless, this method does not solve the large zero count problem since patent collaborations in the dataset are relatively small in magnitude, and adding a small fixed quality between 0 and 1 could have a large impact on the outcome (Santos Silva and Tenreiro, 2006).

innovation. Next, we try to examine how these effects vary under IPR protection. Column (3) adds IPR and the interaction between religious similarity and IPR. Interestingly, the interaction term appears to be significant and negative. It confirms that the positive effect of religious similarity on bilateral innovation amplifies in countries that have inadequate IPR protection. Next, we control for ethnic and language fractionalization of countries in column (5), and results continue to hold. Lastly, we use an alternative measure for the dependent variable. As mentioned previously, the bilateral PCT application data from OECD is limited to few technology domains, and hence, as a robustness check, we use patent granted data from the PATSTAT to reproduce bilateral patent collaborations between 2000 and 2016. The result continues to hold for an alternative measure of the dependent variable.

Table 3.1: Gravity estimates for bilateral patent collaborations (aggregate from 2000-2016)

	Dependent variable using PCT applications					Dependent variable using Patents granted	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
religious similarity		0.820*** (3.305)	7.814*** (5.235)	0.827*** (3.307)	8.085*** (4.956)	0.573* (1.850)	8.339*** (7.021)
religious similarity $\times$ IPR _{ij}			-0.796*** (-4.316)		-0.825*** (-4.132)		-0.888*** (-5.664)
IPR _{ij}			2.304*** (6.302)		0.035 (0.227)		2.537*** (10.118)
Ethic fractionalization _i				-1.008 (-1.641)	8.334*** (10.392)		
Ethic fractionalization _j				-3.276*** (-4.772)			
Linguistic fractionalization _i				0.690 (1.026)	-1.907 (-1.190)		
Linguistic fractionalization _j				5.841*** (6.741)	1.689*** (3.443)		
Ln(distance)	-0.254*** (-6.461)	-0.230*** (-4.189)	-0.228*** (-4.088)	-0.229*** (-4.106)	-0.226*** (-3.986)	-0.084 (-1.138)	-0.079 (-1.057)
Common Language	0.681*** (6.519)	0.656*** (4.436)	0.676*** (4.516)	0.672*** (4.432)	0.692*** (4.511)	1.078*** (5.314)	1.091*** (5.423)
Colonial relationship	0.146** (2.026)	0.191** (2.397)	0.150* (1.915)	0.179** (2.193)	0.139* (1.731)	0.114 (0.753)	0.084 (0.549)
Contiguity	0.409*** (4.317)	0.354** (2.556)	0.355*** (2.599)	0.351** (2.476)	0.352** (2.534)	0.479** (2.095)	0.490** (2.158)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.978	0.983	0.984	0.983	0.984	0.943	0.944
N	4416	2992	1879	2629	1667	8508	4521

Note: The gravity model estimates are based on Poisson pseudo maximum likelihood estimation method. The numbers in parentheses are t-statistics based on robust standard errors clustered at the country level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Dependent variable is the aggregate bilateral patent collaborations between 2000 and 2016. This is based on all patents applications filed at the PCT (Source: OECD database) for technology classes ICT, nanotechnology, biotechnology, and environment-related technologies. Religious similarity and religious diversity are based on religious fractions provided in the McCleary and Barro (2006) database. Data on IPR is from the Ginarte and Park (1997) database. Combined IPR protection (IPR_{ij}) is the sum of IPR protection in country i and country j. Data on bilateral geographic distance, contiguity, common language, and colonial relationship are from CEPII database. Column (6) and (7) use aggregate bilateral patent granted data from patent issuing institutions EPO and WIPO.

To further validate our preliminary results, we control for additional geographical variables. For example, elevated rugged terrains can increase transaction costs and impede knowledge transfer. Next, we test whether other cultural dimensions could potentially confound the results. Hence, we control the gravity model for (1) common religion, a variable that takes the value one if two countries share a common religion, (2) linguistic proximity, (3) genetic proximity, and (4) legal origin after transition from colonial rule. Lastly, the model account for real income, population, trade (WTO membership) and domestic patent stock in countries i and j . Results are robust to alternative explanations, and they are presented in Table 3.A.2 of Appendix A. Overall, our empirical analysis provides preliminary evidence for the relationship between culture, IPR protection, and collaborative innovation.

3.4 Experimental design

We recruited 320 undergraduate students from Nanyang Technological University from various subjects and years of study. The experiment took place between July and August 2020, in the Virtual Laboratory of NTU (Lab VENTU), where subjects participated remotely. The motivation for this was partly due to the Covid-19 pandemic situation where physical experiments were disallowed with social distancing and lockdown measures.²³ All recruitments were voluntary and advertised through open email invitations. The experiment was programmed in Python on an open-source platform known as o-Tree developed by Chen et al. (2016). The experiment included five different treatments, with eight sessions organized per treatment. Each treatment session included eight participants in total. Control questionnaires were used to check participants understanding of the instructions displayed at the beginning of each stage.²⁴ To facilitate communication between the experimenter and subjects, we used a Zoom meeting where audio and video were both disabled, and each participant were assigned a unique experiment ID to avoid using names or labels that would enable them to be identified. Communication was restricted in Zoom to private text messaging with the experimenter. However, subjects were allowed to communicate with the experimenter via private messaging. The purpose of organizing a virtual meeting in Zoom was to convey instructions to participants

²³ Arechar et al. (2018) provides a discussion on the replicability of online experiments. Although there are natural limitations, they find online experimentation to compliment laboratory studies.

²⁴ Apart from displaying the instructions, audio instructions were embedded to the program as well.

prior to the experiment, resolve questions raised by participants, assist participants who are reserves, handle dropouts, push participants who are too slow, and most importantly, retain participants' attention even though they are geographically separated.

3.4.1 Experimental design for Gp.CF.Rt(obs) treatment

(i) **Minimal Groups:** Subjects were asked to show their preference between two colors; Yellow or Red. Unlike the random allocation method, grouping based on preferences allow subjects to identify themselves as part of a group based on a common reason. For example, preference for Yellow over Red may be caused by some reason X commonly shared by all those who favor Yellow over Red. Once participants reveal their preferred color, we assign an equal number of subjects to each color using the median split method. The median split method allows us to determine the “social distance” of each individual from his/her true cultural identity by measuring the deviation of players' true preference from the allocated group. It can be used as a measurement of an individual's true affinity towards group identity. It also enables us to study the behavior of those who are socially distant.

(ii) **Group fate (to elicit beliefs tied to common fate):** According to Corazzini and Sugden (2010), group identity strengthens when members believe they are exposed to a common risk. Hence, we introduce subjects to a lottery that would realize at the end of the experiment. The computer rolls virtual six-sided dice for each group separately. If the randomly determined number is 6, each member of the group will receive a bonus of S\$6. The color of the virtual dice reflected participants' group color. The probability of winning the lottery is 1/6 for all members of the group. Therefore, it generates common beliefs about the success that are tied to group fate (i.e. commonly experienced financial success or failure in the lottery). We refrain from allocating penalties in the lottery to avoid inducing loss anxieties that would adversely affect the purpose of eliciting common fate.

(iii) **Social Interaction Game (SIG to elicit rituals):** We elicit ritual participation by allowing subjects to participate in a series of social interactions with actions guided by rules and values specific to each group. The SIG has three steps.

Step1: Learning the cultural codebook- First, we let individuals learn the rules and values specific to their group by exposing subjects to a series of generic *Actions* and *Contexts* using neutral codified images to avoid importing cultural and gender biases. The *Codebook* of *Actions* and *Contexts* are unique to each group and different from other's *Codebook*. *Actions* are presented across Rows and *Contexts* are presented across Columns. For each Context, there is one correct Action indicated by a tick (✓). A cross (×) indicates incorrect Actions for a given Context. Correct choices contribute to a *Group Score* that has no monetary benefits. Participants must click on “View Codebook” button to see the Codebook; it will appear for 3 seconds per click up to a maximum 5 clicks per round. In each round, *Context* images change at random, and the order of *Actions* change at random. Subjects have the option to move to step 2 without learning the codebook. However, choosing to click on the “View Codebook” button and utilizing the clicks available to view the codebook indicates individuals' commitment to group performance. Figure 3.1 shows an example of a *Codebook* that belongs to the Yellow group.

		Contexts

Actions		✓	✗	✗	✗
	✗	✓	✗	✗
	✗	✗	✓	✗
	✗	✗	✗	✓	

Number of Views Left: 4

[View Codebook](#)

[Continue](#)

Figure 3.1: Example of a Codebook that belongs to the Yellow group.

Step2: Perform the ritual- In this step, all group members see a Context generated randomly by the computer. Next, the participant must choose the correct Action for the given Context according to the group's cultural codebook. Participants will learn about their group members' choices only after they have made their choices in that round. Figure 3.2 shows an example of the task.

Figure 3.2: Example of performing the ritual.

Step 3: Social Interactions- In this step, participants will learn about their commitment to their social group. Once participants confirm their choices, the computer will show the actions chosen by all the group members and indicate whether each action was correct (✓) or incorrect (×). The computer will report the group score. Since rituals are repeated and synchronous acts, each group member will repeatedly perform this task for 15 rounds. Figure 3.3 illustrates the observable ritual.

Figure 3.3: Observable/public ritual

(iv) **Group experience (to elicit cultural experience):** In the same repeated social interaction game, points earned by the group will enhance group experience. For instance, it will create trust and affiliation towards its own cultural group. Since rituals are voluntary commitments with no monetary expectations, the social interaction game does not offer individuals financial incentives.

Our design was guided by two main modeling objectives. First, all social groups observe a certain code of conduct according to their cultural beliefs. Reciting prayers before meals, going to church on Sundays, worshiping elders, observing dietary restrictions, and conforming to certain dress codes are few examples of rituals that people perform repeatedly and synchronously depending on their cultural background. They take time, effort, and resources, hence, costly. During the 15 rounds of SIG, members of the group perform the same task. Deviating from your group's rituals is costly for self-determined individuals. Those who value group identity and feelings of belonging to a group will perform the ritual task well, rather than deviate. Hence, it will enhance group commitment and influence group members to conform and oblige to their own cultural practice. Our first main objective was to provide a generic environment where group-specific social interactions could be performed.

Second, we can quantify the efforts put into performing the rituals using the number of clicks utilized to learn the codebook and observe how efforts vary across ritual manipulations. According to Alan Fiske, collective rituals trigger feelings of potential danger from non-performance (Dulaney and Fiske, 1994; Fiske and Haslam, 1997). For instance, subjects who perform collective rituals may fear social exclusion due to non-performance compared to those who perform private rituals. It leads to hyperactive monitoring of one's actions and behaviors (Hobson et al., 2018), and therefore, collective rituals that are rigid, formal, repetitive, and synchronous demand close attention and focus than private rituals (Boyer and Liénard, 2008). High attention-demand and involvement under observable rituals motivate individuals to memorize the cultural codebook with little effort, whereas low attention from private rituals (unobservable rituals) cause individuals to put more effort into learning the cultural codebooks. Therefore, we should expect lower efforts under observable rituals. Last, we could use the social distance of each player to observe whether individuals with high social distance are likely to respond differently from their own code of conduct more frequently or not. We can monitor these subjects more closely to understand their group commitments.

(v) **Dynamic Games (DYG):** After completing SIG, participants play 10 dynamic games; five from Gächter et al. (2010) knowledge sharing game and five prosocial games. In Gächter et al. (2010) sequential knowledge sharing game, both leader (L) and follower (F) have the choice to either share(s) or conceal (c) their knowledge from the other inventor. The leader always makes the first

decision to share or conceal knowledge and the follower makes the decision to share or conceal knowledge irrespective of leader's decision. Once, the follower makes the decision, the game ends, and the payoffs b_i are realized for both players (i.e. $b_i > 0$ for $i=L, F$). This is a base payoff received by both inventors for their effort even if they choose to conceal knowledge. For instance, inventors may put effort in the innovative process without any expectation of collaboration from other inventors. Next, the value enhancement of sharing knowledge with fellow player is denoted by v_i (e.g. $v_i > 0$ for $i=L, F$). That is, if Leader shares his/her knowledge with the follower, irrespective of follower's decision to share or conceal his/her knowledge, follower's knowledge enhancement from leader's decision to share knowledge is, v_F . Likewise, if follower shares his/her knowledge with the leader, leader receives a value enhancement of v_L . Similar to Gächter et al. (2010), we simplify the experiment by setting $b_L = b_F = b = 10$ and $v_L = v_F = v = 20$.

Next, the exclusivity payoff a_i in Gächter et al. (2010) model capture the benefit from exclusive appropriation for players who choose to conceal knowledge when other player has shared. That is, if leader shares while follower conceals, follower may enjoy the exclusivity benefit a_F . In our experiment, we use the exclusivity payoff as a measurement of IPR protection or the rule of law. For example, high exclusivity payoff indicates a higher incentive to deviate from sharing knowledge. This would resemble an environment with weak IPR protection. Conversely, a low exclusivity benefit indicates an environment with high IPR protection; since the incentive from exclusive appropriation is low, the incentive to deviate from sharing knowledge is minimized. To vary the level of IPR protection, we follow three levels of exclusivity parameter. That is, $a_{L,F}$ equal 0, 20, and 30. Similar hold for the leader as well. According to Gächter et al. (2010), exclusivity payoff resemble the opportunity cost of knowledge sharing. Lastly, k capture transaction costs involved during explicit knowledge sharing and assumed to be zero.

The five prosocial games include Kind Trust Game (KTG), Unequitable Trust Game (UTG), Needy Trust Game (NTG), Dictator Game (DG), and Ultimatum Game (UG). These investigate prosocial behaviors towards trust, trustworthiness, reciprocity, altruism, and fairness. For example, in the trust game introduced by Berg et al. (1995), a sender can transfer a part of an endowment to a receiver. If the sender chooses to trust the receiver, the endowment will multiply by some factor K (e.g., doubled or tripled). The receiver could honor the trust and return full or partial endowment to the sender

or abuse the trust by keeping the endowment without repercussions. Self-interested money maximizing receiver will retain the endowment, and expecting this behavior, the sender will not share the endowment with the receiver leading to a subgame perfect Nash equilibrium with zero transfers between the sender and the receiver. Deviating from pure self-interested behavior, senders and receivers were both found to be more trusting and trustworthy in laboratory settings (Kreps, 1990; Berg et al., 1995). UTG, KTG, and NTG adopted in this study are variants of the basic trust game (Bacharach et al., 2007; Tan and Zizzo, 2008). For instance, trusting is a “kind” act performed by the sender resulting in higher payoffs than would not have trusted the receiver. The needy trust game makes the sender “needy” of trust since if he/she does not trust the receiver, the sender will be in a worst-off position.

Unequitable Trust Game is equivalent to the KTG, but with 10 points added to the sender's payoff values and 10 points subtracted from the receiver's payoff values. The trust responsiveness should be low for UTG and gradually increase over KTG and NTG. In a similar vein, the ultimatum game offers to split an endowment between two agents: proposer and responder. The responder could choose to accept or reject the offer made by the proposer. If the responder rejects, both receive nothing. Rational and money maximizing responders must accept any positive amount, albeit small. However, Güth et al. (1982) find responders to reject endowments below a certain threshold as an altruistic punishment for unfair offers. In the dictator game, a sender can offer any positive amount to the responder, and the recipient has no influence over the outcome, unlike in the ultimatum game. Homo economicus senders would prefer to maximize their payoffs resulting in zero transfers to the recipient. However, in both the dictator game and ultimatum games, the proposer offered positive endowments to the responder demonstrating the altruistic and inequity aversion behavior of agents. Hence, it is crucial to test whether subjects exhibit these social value orientations when the degree of social identity varies.

Table 3.2 shows the payoffs for each of the 10 games in DYG. In the experiment, we are keen to understand how the decision to share or conceal knowledge varies when there is a trust element to complement the behavioral choices. To test this hypothesis, participants will make their decisions with their group identity exposed. That is, the group color of the participant (Yellow or Red) will be visible to the coparticipant and vis-à-vis. The objective is to test the willingness to share among ingroup and outgroup members. Hence, participants make 20 decisions with 10 games played with ingroup members and 10 games

played with outgroup members. No value-laden markers or names were used in the experiment.²⁵ Gender-neutral icons were used to display group color. Participants were not informed or given feedback on the outcome until the end of the experiment, so as to avoid supergame effects and independence across tasks. Games were presented in randomized order to indirectly control for undesirable order effects.

Table 3.2: Dynamic games

KSG-1 ($a_L=0, a_F=0$)		KSG-2 ($a_L=20, a_F=0$)		KSG-3 ($a_L=0, a_F=20$)		KSG-4 ($a_L=20, a_F=20$)		KSG-5 ($a_L=30, a_F=30$)	
30, 30	10, 30	30, 30	10, 30	30, 30	10, 50	30, 30	10, 50	30, 30	10, 60
30, 10	10, 10	50, 10	10, 10	30, 10	10, 10	50, 10	10, 10	60, 10	10, 10
KTG		UTG		NTG		UG		DG	
30, 30	10, 50	40, 20	10, 50	30, 30	10, 50	30, 30	0, 0	30, 30	30, 30
10, 10	10, 10	20, 0	20, 0	0, 20	0, 20	50, 10	0, 0	50, 10	50, 10

Note: The italics stand for cooperative solution in the game. In the KSGs, the equilibrium strategies depend on the a_L and a_F . Refer to Gächter et al. (2010) for the various mixed strategy equilibria. In the experiment cooperative outcomes were not highlighted in anyway. In each game, actions available to both leader and follower were labelled as A or B to avoid value-laden labels.

(vi) **Questionnaire:** Once all decision tasks complete, individuals participate in a self-administered questionnaire to capture demographic characteristics of individuals (e.g., age, nationality, religion, education, and many others).

(vii) **Payment:** Lastly, subjects were paid according to the rules of the game. Each session lasted for approximately 1 hour. At the end of the experiment, one round from the dynamic games was randomly selected for payment (1 experimental point = S\$0.02). Each participant received a show-up fee of S\$5. Participants had the opportunity to earn money from the show-up fee, lottery, and dynamic games. The average earning was S\$11 for one hours of work and equaled to the experiment's expected earnings.²⁶

²⁵ In laboratory experiments, it is crucial to avoid value-laden content labels for choices as decisions may get swayed by home-grown heuristics (e.g., habits, values, and norms). Additionally, players decisions may bias towards positively framed choices rather than economic incentives. Therefore, choices were framed neutrally, and the game was not referred as a knowledge sharing game. The games payoff structure was designed to capture the value of knowledge sharing using induce-value methodology whereby we assume subjects perceive value of knowledge sharing from the incentives rather than the task itself. Therefore, decisions were neutrally framed as “A” or “B” rather than “share” or “conceal”. Moreover, players were not referred to as “leaders” or “followers,” but as “decision maker 1 and 2.”

²⁶ This is comparable to the average student assistants' earnings of \$10 per hour at Nanyang Technological University.

3.4.2 Treatments

Baseline/Control treatment- In the baseline treatment, we run the experiment with no groups. Adopting a similar experimental design in the control session is crucial to eliminate endogenous group effects. In stage 1, we do not assign subjects to groups based on color preference. Instead, subjects were informed about an individual lottery that would realize at the end of the experiment. This is to simulate individual fate, unlike the common fate induced in the *Gp.CF.Rt (obs)* treatment. To elicit individual fate, the computer rolls a virtual six-sided dice for each subject, separately. If the randomly determined number is 6, each subject received a bonus of S\$6. In stage 2, unique codebooks were assigned to each of the eight subjects in the session.

Similar to the *Gp.CF.Rt (obs)* treatment, subjects learn the codebook in step 1 of stage 2 before performing the ritual of selecting correct actions according to the context generated by the computer in step 2. Next, in step 3 of stage 2, the program acknowledges whether it is the correct action or not while reporting the individual performance score. Unlike the *Gp.CF.Rt (obs)* treatment, the ritual task in the baseline treatment is performed privately. Next, subjects participated in the standard dynamic games. Since there are no group formations in the control treatment, gender-neutral silhouette icons resembled the coparticipant's identity. To mirror the *Gp.CF.Rt (obs)* treatment, subjects repeatedly played DYG games twice in order to have 20 rounds in stage 3 for the baseline treatment for comparison purposes. Since endogenous group effects did not drive individual decisions, we can use the baseline experiment as a benchmark to test our hypotheses.

In addition to the baseline treatment, we conducted three other treatments to test the significance of each dimension: common beliefs, fate, and rituals. *Gp.IF.Rt(obs)* treatment includes SIG task with observable rituals but accounts for individual faith in contrast to common faith in *Gp.CF.Rt(obs)* treatment. To induce individual faith, colored dices (Red or Yellow) were rolled out separately for each player. It renders a comparison between *Gp.IF.Rt(obs)* and *Gp.CF.Rt(obs)* treatments to identify the effects of common faith on group biases when rituals are observable or public.

In *Gp.CF.Rt(ind)* we induce common faith with unobservable rituals. That is, subjects perform the same ritual task in *Gp.CF.Rt(obs)* treatment without any feedback. That is, the social interaction game in *Gp.CF.Rt(ind)* treatment is a private ritual. A comparison of *Gp.CF.Rt(obs)* and *Gp.CF.Rt(ind)* enable us to compare the effects of private and public rituals on ingroup biases

in the presence of a common faith. Lastly, we include Gp.IF.Rt(ind) treatment where subjects are administered into minimal groups but induce individual faiths and the SIG is a private ritual.

Table 3.3 Panel A illustrates the differences between the five treatments conducted in the study. Please refer to Appendix B for a detailed description of the instructions for each treatment.

Table 3.3: Summary of treatments

Panel A: Differences between treatments													
Treatment	Stage 1			Stage 2			Stage 3						
	Minimal Groups		Common Fate	Rituals			Dynamic Games						
Gp.CF.Rt(obs)	Yes		Yes- Group lottery			Observable SIG				Yes			
Gp.IF.Rt(obs)	Yes		No- Individual lottery			Observable SIG				Yes			
Gp.CF.Rt(ind)	Yes		Yes- Group lottery			Unobservable SIG				Yes			
Gp.IF.Rt(ind)	Yes		No- Individual lottery			Unobservable SIG				Yes			
Baseline	No		No- Individual lottery			Individual SIG				Yes			

Panel B: Summary Statistics														
Treatment	No. of Sessions	No. of participants	SIG Individual Score				SIG Group Score				Average points earned in DYG games	Earnings (SGD)		
			Min	Max	Mean	Median	Min	Max	Mean	Median		Min	Max	Mean
Gp.CF.Rt(obs)	8	64	11	15	14	15	50	60	57	59	25	5	23	11
Gp.IF.Rt(obs)	8	64	7	15	14	15	49	60	56	57	25	5	23	11
Gp.CF.Rt(ind)	8	64	3	15	14	15	45	60	56	57	24	5	21	11
Gp.IF.Rt(ind)	8	64	5	15	14	15	49	60	57	58	22	5	21	11
Baseline	8	64	9	15	14	14	-	-	-	-	21	7	21	10
Total	40	320	3	15	14	15	45	60	57	57	23	5	23	11

Note: Observable SIG resemble public rituals where members of the group observe the actions chosen by the participant in step 3 of stage 2 in the Gp.CF.Rt(obs) treatment design. Conversely, unobservable SIG resemble private rituals where Participants do not receive feedback on the actions chosen by members of the group in the SIG task. Figure 3.4 shows an example for the unobservable rituals.

Figure 3.4: Private/unobservable ritual

3.5 Experimental results

Panel B of Table 3.3 provides summary statistics for the experimental outcomes across treatments. Out of the 320 undergraduate students, the mean age of participants was 21 years, with approximately 40% males. The median individual SIG score is 14 for the baseline and 15 for the other treatments. A perfect median score in the SIG, reflects high level of engagement in the non-incentivized task. The group's median SIG scores varied across treatments, with the highest score reported in *Gp.CF.Rt(obs)* treatment. The average points earned in the dynamic games decrease across treatments and indicates declining efficiency with weakening social identities. Table 3.4 reports the average sharing rates of the leader and follower across treatments and games.

Table 3.4: Sharing rates across treatments and games.

Panel A: Average sharing rate across treatments			
Treatment	Leaders sharing rate	Followers sharing rate contingent on Leader sharing	Followers sharing rate contingent on Leader concealing
Gp.CF.Rt(obs)	0.50	0.31	0.45
Gp.IF.Rt(obs)	0.50	0.39	0.56
Gp.CF.Rt(ind)	0.50	0.35	0.60
Gp.IF.Rt(ind)	0.47	0.38	0.51
Baseline	0.46	0.36	0.47
Panel B: Average sharing rate across games			
Treatment	Leaders sharing rate	Followers sharing rate contingent on Leader sharing	Followers sharing rate contingent on Leader concealing
KSG-1 ($a_L=0, a_F=0$)	0.61	0.61	0.47
KSG-2 ($a_L=20, a_F=0$)	0.38	0.59	0.41
KSG-3 ($a_L=0, a_F=20$)	0.55	0.21	0.48
KSG-4 ($a_L=20, a_F=20$)	0.31	0.21	0.49
KSG-5 ($a_L=30, a_F=30$)	0.27	0.16	0.46
UTG	0.53	0.21	
KTG	0.72	0.11	
NTG	0.85	0.21	
UG	0.34	0.93	0.80
DG	0.30		

3.5.1 Does common fate and rituals affect SIG performance?

First, we test whether common fate and rituals increase group performance and strengthen individuals' group identity. Figure 3.5 demonstrates individual SIG performance in time t against SIG performance in time $t-1$. A positive correlation indicates that SIG performance increases over time, and the slope indicates the rate of increase. In Figure 3.5.a, we compare SIG performance in *Gp.CF.Rt(obs)* treatment against *Gp.IF.Rt(obs)*. Both

treatments comprise of minimal group formations and observable rituals. The only difference stems from the absence of common fate in $Gp.IF.Rt(obs)$ treatment. Figure 3.5.a shows that the rate of increase in SIG performance in $Gp.CF.Rt(obs)$ treatment is higher than $Gp.IF.Rt(obs)$ treatment. Hence, common fate reinforces group performance in the presence of observable rituals. Next, Figure 3.5.b compares the SIG performance between $Gp.CF.Rt(obs)$ treatment and $Gp.CF.Rt(ind)$ treatment. Any difference should highlight the impact of observable (public) rituals compared to unobservable (private) rituals. The slope of $Gp.CF.Rt(obs)$ treatment is higher than the slope of $Gp.CF.Rt(ind)$ treatment. It reveals that performing synchronous and repetitive tasks are not sufficient to increase group performance unless all members observe each other's ritual commitments.

Result 1.1: *Observable rituals and common fate mutually reinforce each other.*

Figure 3.5: SIG performance in T against SIG performance in T-1

Next, we investigate the efforts in the social interaction game. In the SIG design, subjects can click on the “View Codebook” button to learn the codebook in each period up to a maximum of 5 times. The decision to click on the “View Codebook” and the number of times to click depends on individual choice. Therefore, the number of clicks utilized reflects individual efforts to learn the codebooks. Figure 3.6 shows that SIG performance and efforts diverge over time resulting in a negative correlation between SIG and efforts. The correlation

between SIG score and efforts for *Gp.CF.Rt(obs)* treatment is -0.58, followed by *Gp.IF.Rt(obs)* (-0.38), *Gp.CF.Rt(ind)* (-0.18), *Gp.IF.Rt(ind)* (-0.17) and, *Baseline* (-0.06). The negative correlation between SIG performance and efforts reveals that learning ability increases over time. A comparison of efforts between observable and unobservable rituals in Figures 3.6.a and 3.6.b reveals that, observable rituals are associated with low efforts due to high attention demand and focus required by public rituals.

Result 1.2: *Observable rituals require lower efforts.*

Figure 3.6: Distribution of efforts and SIG score

3.5.2 Do Leaders and Followers exhibit prosocial behavior?

Figure 3.7.a illustrates leaders' and followers' trusting and trustworthy behaviors in each prosocial game differentiated by treatment.²⁷ As expected, trusting rate is high in NTG followed by KTG and UTG for the Leader. We observe the same pattern for the follower as well. In the DG and UG games, leaders' trust rate is approximately 30%. Hence, leaders are more altruistic and giving than a typical self-concerned rational agent. Roughly, fading trust rates shown by the color intensities of markers reveal that leaders trust more in *Gp.CF.Rt(obs)* treatment and trust gradually decrease with weakening group identity over treatments. However, this appears less prominent in the follower's trust games.

²⁷ In Figure 3.7.a, data labels _L and _F refers to the leader and the follower.

Figure 3.7.b shows the follower's responsiveness to fair and unfair offers made by the leader in the ultimatum game. Overall, the rejection rates are relatively low (approximately 20%), indicating that followers are more tolerant and willing to accept lower offers regardless of various social manipulations. A breakdown of the responsiveness to ingroup and outgroup members is shown in Figure 3.A.1 in Appendix A. Overall rejection rates are high for outgroup members relative to ingroup members.

Result 1.3: *Leaders are more trusting and altruistic, whereas followers are more trustworthy and more tolerant.*

Figure 3.7: Social value orientations for the Leader and the Follower

Table 3.5: Prosocial behavior towards ingroup members relative to outgroup members for the leader and Follower

	Leader trusting behavior						Leader sharing behavior			
	UTG		KTG		NTG		UG		DG	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Ingroup	0.348*** (3.919)	0.301*** (4.035)	0.295** (1.981)	0.267* (1.790)	0.095 (0.080)	0.076 (0.389)	0.262 (1.115)	0.257 (0.959)	0.020 (0.269)	-0.096** (-2.244)
Common Fate		-0.065 (-0.592)		0.347** (2.209)		0.307 (1.520)		-0.201 (-1.194)		0.464*** (9.345)
Ritual		0.368*** (3.100)		-0.155 (-1.055)		-0.197 (-0.756)		0.222 (1.550)		0.246** (2.562)
Constant	1.018 (0.065)	1.954 (0.123)	-20.373*** (-4.116)	-20.956*** (-4.677)	-27.402 (-0.958)	-28.646 (-1.166)	28.292*** (4.721)	28.590*** (4.403)	2.628 (0.213)	3.173 (0.275)
Ind. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	.0318	.0439	.1004	.1116	.0877	.1002	.0993	.1037	.0313	.0529
N	320	320	320	320	320	320	320	320	320	320
	Followers trustworthy behavior after leader trust						Followers sharing behavior			
	UTG		KTG		NTG		UG (Ls)		UG (Lc)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Ingroup	-0.279 (-1.377)	-0.212 (-1.223)	-0.326** (-2.248)	-0.283** (-2.065)	0.061 (0.330)	0.155* (1.922)	-0.128 (-0.389)	-0.207 (-0.605)	0.322 (1.231)	0.323 (1.139)
Common Fate		-0.377 (-1.616)		-0.480*** (-5.426)		-0.545*** (-5.547)		-0.093 (-0.181)		-0.019 (-0.153)
Ritual		-0.064 (-0.219)		0.156 (1.571)		-0.108 (-0.760)		0.679 (1.197)		0.013 (0.096)
Constant	-27.366*** (-3.545)	-26.837*** (-3.950)	-66.689*** (-3.463)	-66.386*** (-3.324)	-80.737*** (-3.356)	-79.370*** (-3.300)	23.881 (0.872)	24.989 (0.970)	13.925 (0.655)	13.974 (0.653)
Ind. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	.0424	.0503	.1442	.1576	.2078	.2145	.0906	.1153	.0716	.0716
N	306	306	320	320	320	320	306	306	320	320

Note: The numbers in parentheses are t-statistics from a logit regression with random effects and robust standard errors. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. The individual controls include age, age squared, male, catholic, ethnicity Chinese, middle income, and subject background applied sciences. The regressions exclude the baseline treatment as there are no groupings to measure ingroup biases. Therefore, we do not include minimal groups as a variable of interest as the rest of the treatments considered in this table all include minimal groups. Hence, it will not have any explanatory power.

Next, we try to differentiate prosocial behavior towards ingroup and outgroup members. The “ingroup” variable is a binary variable that equals one if the participants’ group is the same as the coparticipants group and zero, otherwise. Hence, it is a measure of sharing rate to ingroup members relative to outgroup members. Table 3.5 presents regression estimates for binary logit with random effects and robust standard errors. In the trust games, UTG and KTG show positive and significant biases toward ingroup members. However, in the NTG, subjects need to trust the follower regardless of their group identity to earn money as the dominant strategy is to take a chance and trust. Therefore, trust in the NTG is trivial for ingroup members and explains the insignificant ingroup biases observed for the leader. It has often been argued and found that first mover's (in our case leader) behavior in the UG is driven by fear of rejection and beliefs of second mover's social preferences rather than the first mover's social preferences per se (Fehr and Schmidt, 2006). Therefore, we do not observe significant ingroup biases in the UG for the leader.

Next, we look at the followers’ trusting behavior when the leader share. Although followers appear to be more trusting of their group members in the NTG, surprisingly, we observe negative and significant bias for ingroup members in the KTG. To understand this further, we look at the average sharing rates between ingroup and outgroup members and learn that the sharing rate towards outgroup members is higher than ingroup members on average (except in NTG). Therefore, followers do not show strong ingroup biases in the trust games.

Result 1.4: *Leaders show ingroup favoritism in unequitable and kind trust games.*

Result 1.5: *Followers do not show strong preference for ingroup members in trust games.*

Figure 3.8: Difference between ingroup and outgroup sharing in KSG

3.5.3 Cultural similarity biases knowledge sharing

Table 3.A.3 in Appendix A shows the sharing rate decrease over KSGs for both the leader and the follower. Since high exclusive appropriation parameter mirrors low IPR protection, decreasing sharing rates over KSGs suggests that low IPR protection hinders cooperation among individuals regardless of various cultural manipulations. Although expected, we do not observe sharing rates to decrease across treatments with weakening cultural formations. A possible reason could be that individuals with low group identity (also known as low SIG performers moving forward) wipe out some of the effects. Hence, it is crucial to differentiate sharing rates by SIG performance.

Figure 3.8 illustrates the difference in ingroup and outgroup sharing rates for KSGs differentiated by individual SIG performance. We consider participants who scored above the average individual median score (i.e., 15) as *high SIG performers* and others as *low SIG performers*. Figure 3.8 show a positive difference in the sharing rates between ingroup and outgroup members for high-performing leaders and followers in the SIG. Among high performing leaders in Figure 3.8.a, the difference in sharing rates decrease over cultural manipulations. i.e., leaders discriminate more against outgroup followers with stronger group identity manipulations relative to weak group identities. In the *Gp.CF.Rt(obs)* treatment, the average sharing rate with ingroup members is 0.53 while it is 0.40 for outgroup members (refer to Table 3.6). The difference is statistically significant (Mann-Whitney $p=0.06$). The mean differences in sharing rates become statistically insignificant for the other treatments. Hence, it is evident that weak cultural identities hinder ingroup vs. outgroup discriminations for the leader.

Unlike the leader, followers are expected to be unbiased between ingroup and outgroup members when the leader commits to share knowledge. We observe this for *Gp.CF.Rt(obs)* treatment in Figure 3.8.b as the difference in the sharing rates are relatively small and close to zero compared to others (Mann-Whitney $p=0.75$). However, followers appear to be more discriminatory towards outgroup members, with weakening group identity manipulation.

Table 3.6: Average sharing rates between ingroup and outgroup members across treatments for high SIG performers.

	Leader's sharing decision			
	Gp.CF.Rt(obs)	Gp.IF.Rt(obs)	Gp.CF.Rt(ind)	Gp.IF.Rt(ind)
Mean ingroup sharing	0.53	0.46	0.39	0.45
Mean outgroup sharing	0.40	0.37	0.43	0.43
Difference	0.13 (0.06*)	0.09 (0.53)	-0.04 (0.67)	0.02 (0.66)
	Followers' share decision after Leader share			
	Gp.CF.Rt(obs)	Gp.IF.Rt(obs)	Gp.CF.Rt(ind)	Gp.IF.Rt(ind)
Mean ingroup sharing	0.26	0.45	0.37	0.44
Mean outgroup sharing	0.25	0.35	0.30	0.35
Difference	0.01 (0.75)	0.10 (0.28)	0.07 (0.52)	0.09 (0.52)
	Followers' share decision after Leader conceal			
	Gp.CF.Rt(obs)	Gp.IF.Rt(obs)	Gp.CF.Rt(ind)	Gp.IF.Rt(ind)
Mean ingroup sharing	0.46	0.58	0.68	0.44
Mean outgroup sharing	0.24	0.45	0.56	0.35
Difference	0.23 (0.01)**	0.13 (0.05)*	0.12 (0.03)**	0.09 (0.29)

Note: *P* values from the Mann-Whitney *U* test are in parentheses

Conversely, followers show strong ingroup biases when leaders conceal knowledge. This is apparent in Figure 3.8.c. Mann-Whitney *p* values for the differences in sharing rates are highly significant across treatments. Figures 3.8.b and 3.8.c suggest that followers' decision to discriminate against outsiders largely depends on how they reciprocate to leaders' knowledge sharing decision. Overall, Figure 3.8 provides descriptive evidence to support our first theoretical prediction that cultural similarities promote knowledge sharing.

Contrary to high SIG performers, low SIG performers appear less discriminatory towards outsiders due to weak group effects caused by low performance in the ritual task. For example, the difference in sharing rates for the *Gp.CF.Rt(obs)* treatment is zero for the leader and less than 0.06 for the follower. In Figure 3.8, a comparison of sharing rates in *Gp.CF.Rt(obs)* vs. *Gp.CF.Rt(ind)* treatments (i.e., blue vs. green bars) and *Gp.IF.Rt(obs)* vs. *Gp.IF.Rt(ind)* treatments (i.e., orange vs. yellow bars) reveals that the ritual task negatively affect ingroup biases among low SIG performers. This has led to higher knowledge sharing with outgroup members than ingroup members. On the other hand, a comparison of sharing rates between *Gp.CF.Rt(obs)* and *Gp.IF.Rt(obs)* (i.e., blue vs. orange bars) show that common fate mitigates negative effects from ritual participation as the difference in sharing rates changes from negative to positive. A comparison between *Gp.IF.Rt(ind)* and *Gp.CF.Rt(ind)* treatments among low SIG followers reinforce this result.

Result 2.1: *We observe strong ingroup favoritism and outgroup discrimination among high performing leaders and followers in the SIG.*

- (i) Leaders discriminate more against outgroup followers when group identity manipulations are stronger.*
- (ii) If the leader shares knowledge, followers do not discriminate outgroup leaders.*
- (iii) If the leader conceals knowledge, followers discriminate more against outgroup leaders when group identity manipulations are stronger.*

Result 2.2: *Common fate mitigates negative effects of ritual participation among low SIG performers.*

As a robustness check, we use an alternative categorization for SIG performance by considering individual and group SIG performances. Figure 3.A.2 in Appendix A shows the distribution of sharing rates between ingroup and outgroup members under four different SIG performance categories. Overall, figures from the alternative classification reinforce results in 2.1 and 2.2.

To further examine whether leaders and followers show positive and negative discrimination towards ingroup and outgroup members, respectively, we run a series of regressions, and Table 3.7 reports the results. We differentiate sharing rates between ingroup and outgroup members relative to the baseline treatment. The regressions include three-level interactions between minimal groups, common fate, and rituals to identify whether they individually or jointly induce intra-group and intergroup biases. Table 3.7 panel A provides binary logit estimates for high SIG performers. Columns (1) and (2) presents regression estimates for the leader. In column (1), results show that minimal groups, common fate, and rituals are jointly necessary to induce positive discrimination towards ingroup members. Although column (2) hints at negative bias towards outgroup members, it is not sufficient to claim that negative discrimination increases with strong cultural manipulations.

Next, we look at the sharing rates of the follower conditional on leader sharing. Columns (3) and (4) report the results. Interestingly, followers show negative discrimination towards ingroup members when leaders share knowledge. A possible reason could be the collapse of ingroup favoritism due to intra-group competition (Zuo et al., 2018). A closer look at the payoff matrices in KSG 1-3 (refer to Table 3.2) reveal that followers' payoffs are affected by any favorable action towards ingroup member when the leader shares knowledge.

Hence, self-interested followers will prefer to maximize their gains rather than reciprocate leading to the collapse of ingroup favoritism. Therefore, in line with our previous result, followers do not show ingroup biases when the leader shares. Unlike the leader's situation, strong group identification is insufficient to overturn the negative effect of intra-group competitiveness on ingroup favoritism. In column (4), the negative discrimination towards outgroup members is relatively higher than in ingroup members for weak group manipulations resulting in a net positive difference in the sharing rates as observed in Figure 3.8.b. Additionally, minimal group manipulations are sufficient to yield discrimination between groups.

Columns (5) and (6) present the regression estimates for ingroup and outgroup members when the leader conceals knowledge. Payoff matrices in KSG suggest that followers' payoffs are not affected by their sharing decision when the leader conceals. With no intra-group competition, we observe ingroup favoritism to dominate, leading to positive discrimination towards ingroup members. Overall, the strength of intragroup competitiveness determines the net effect of ingroup favoritism for the follower. Furthermore, minimal groups are sufficient to induce negative discrimination toward outgroup members.

Lastly, we repeat the analysis for the low SIG performers. Table 3.7 Panel B reports the results. Unlike the high SIG performers, positive discrimination is shown towards ingroup members by both leaders and followers. We do not observe strong evidence for negative discriminations against outgroup members.

Result 3.1 *When leader shares knowledge, intra-group competition lowers ingroup favoritism among high SIG performers. When leader conceals, intragroup competition has no effect on ingroup biases, thus creating positive discrimination towards ingroup leaders. Minimal groups are sufficient to induce negative discrimination towards outgroup leaders.*

Result 3.2 *Among low SIG performers, positive discrimination is shown towards ingroup members by both leaders and followers. Followers do not discriminate against outgroup members.*

Table 3.7: Regressions on knowledge sharing decisions relative to baseline treatment.

Panel A: Ingroup and outgroup sharing among high SIG performers						
	Dep variable = Ls		Dep variable = Fs/Ls		Dep variable = Fs/Lc	
	Ingroup sharing (1)	Outgroup sharing (2)	Ingroup sharing (3)	Outgroup sharing (4)	Ingroup sharing (5)	Outgroup sharing (6)
1. Mini. Groups × 0. Common Fate × 0.Obs. Rituals	-0.122 (-1.371)	0.138 (1.049)	-0.057 (-1.238)	-0.413*** (-7.947)	-0.094 (-0.840)	-0.522*** (-4.450)
1. Mini. Groups × 0. Common Fate × 1. Obs. Rituals	0.192 (1.204)	-0.181* (-1.667)	-0.051 (-0.336)	-0.545*** (-2.721)	0.310* (1.807)	-0.166 (-0.869)
1. Mini. Groups × 1. Common Fate × 0. Obs. Rituals	-0.205*** (-2.760)	0.098 (1.088)	-0.265*** (-5.108)	-0.565*** (-6.451)	0.827*** (3.905)	0.300* (1.783)
1. Mini. Groups × 1. Common Fate × 1. Obs. Rituals	0.371*** (3.804)	-0.007 (-0.051)	-0.983*** (-4.540)	-1.034*** (-3.686)	-0.259 (-1.313)	-1.284*** (-4.438)
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
R ²	.0482	.0224	.0714	.0655	.1065	.1418
N	500	500	540	540	540	540
Panel B: Ingroup and outgroup sharing among low SIG performers						
	Dep variable = Ls		Dep variable = Fs/Ls		Dep variable = Fs/Lc	
	Ingroup sharing (1)	Outgroup sharing (2)	Ingroup sharing (3)	Outgroup sharing (4)	Ingroup sharing (5)	Outgroup sharing (6)
1. Mini. Groups × 0. Common Fate × 0.Obs. Rituals	0.489*** (5.111)	-0.061 (-1.476)	0.114 (0.591)	0.154 (0.633)	1.044*** (2.868)	0.648** (2.024)
1. Mini. Groups × 0. Common Fate × 1. Obs. Rituals	0.333** (2.318)	0.725*** (17.850)	0.298 (1.005)	0.347* (1.751)	-0.183 (-0.374)	-0.175 (-0.449)
1. Mini. Groups × 1. Common Fate × 0. Obs. Rituals	0.809*** (5.476)	0.587*** (7.021)	0.483** (2.047)	-0.302 (-1.566)	0.790*** (4.209)	-0.740*** (-8.429)
1. Mini. Groups × 1. Common Fate × 1. Obs. Rituals	0.076 (0.512)	0.112 (1.639)	0.150 (0.647)	0.140 (1.218)	0.064 (0.198)	-0.413* (-1.860)
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
R ²	.1362	.1043	.1043	.1896	.2697	.2503
N	500	500	540	540	540	540

Note: The numbers in parentheses are t-statistics based on robust standard errors clustered at the country level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. The models control for individual heterogeneities using age, gender, religion, ethnicity, income level, and subject background of individuals.

3.5.4 Effects of cultural similarity and IPR protection on knowledge sharing behavior

Next, we conduct a series of regression analyses to establish the relationship between cultural similarity, IPR protection, and its interaction on KSGs. Table 3.8 presents logit estimates for the leader and follower's sharing decisions differentiated by individual and group SIG performances. If both leader and the follower are from the same group, the ingroup variable equals one and resembles cultural similarity between the leader and the follower. The exclusive appropriation parameter varies at three levels for the leader and the follower. It is represented by a_L and a_F in the regressions, respectively. Additionally, $a_L \times a_F$ denotes joint IPR protection in both leader and followers' environments. To capture the combined effect of cultural similarity and IPR, we include interactions between cultural similarity, a_L , a_F , and $a_L \times a_F$ variables in the regression models. Next, the interaction between common fate and ritual dummies captures the heterogeneities at the treatment level.

Column (1) shows that cultural similarity represented by ingroup membership has a positive effect on the leaders' knowledge sharing decision when both individual and group SIG performances are high. Similar holds for the follower when leader shares knowledge in column (2). The exclusive appropriation variable has a negative effect on both leader and followers' sharing decisions under all SIG classifications. Recall that exclusive parameter and IPR protection is inversely related. Therefore, a negative and significant exclusivity parameter implies positive effect of IPR on knowledge sharing decisions. The interaction terms $\text{Ingroup} \times a_L$, $\text{Ingroup} \times a_F$ and $\text{Ingroup} \times a_L \times a_F$ appear positive and significant in columns (2)-(4), (7), and (8). It indicates that the interaction between cultural similarity and IPR has a negative effect on leaders' and followers' knowledge sharing decision. Both common fate and rituals positively affect knowledge sharing decisions among high SIG performers. These results are highlighted in blue in Table 3.8. Among low SIG performers, common fate and rituals have a negative effect on knowledge sharing decisions. This supports the weak group hypothesis. Table 3.A.4 presents the marginal effects.

Result 4.1: *Cultural similarity and IPR protection has a positive effect on knowledge sharing decisions.*

Result 4.2: *The positive effect of Cultural similarity on knowledge sharing decisions increase its prominence in the presence of weak IPR protection.*

Table 3.8: Regression estimates for the knowledge sharing decision of the Leader and the Follower

	High individual SIG performance						Low individual SIG performance					
	High group performance			Low group performance			High group performance			Low group performance		
	L _s	F _s /L _s	F _s /L _c	L _s	F _s /L _s	F _s /L _c	L _s	F _s /L _s	F _s /L _c	L _s	F _s /L _s	F _s /L _c
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1.Ingroup	0.272** (2.075)	0.483*** (2.582)	0.244 (1.525)	-0.255 (-0.445)	-0.183 (-0.343)	0.421 (0.966)	-1.236*** (-2.840)	0.142 (0.214)	1.382*** (3.617)	1.382*** (3.617)	0.466 (0.797)	0.560 (0.976)
a _L	-0.041*** (-2.997)	-0.005 (-0.219)	-0.022 (-0.922)	-0.037 (-1.211)	-0.033 (-0.672)	-0.007 (-0.469)	-0.141*** (-3.254)	-0.054*** (-3.218)	-0.018 (-0.962)	-0.018 (-0.962)	0.002 (0.115)	-0.021 (-0.904)
a _F	-0.030 (-1.526)	-0.163*** (-3.873)	0.012 (0.312)	0.071 (0.443)	-0.340*** (-6.616)	0.012 (0.290)	-0.211*** (-3.216)	-0.105 (-1.553)	0.068 (0.515)	0.068 (0.515)	-0.078* (-1.747)	-0.016 (-0.639)
a _L × a _F	-0.001* (-1.798)	0.000 (0.257)	0.000 (0.268)	-0.002* (-1.956)	0.007*** (2.787)	-0.000 (-0.001)	0.001 (0.405)	0.000 (0.041)	0.003** (2.170)	0.003** (2.170)	-0.001 (-0.359)	0.001 (0.684)
1.Ingroup × a _L	-0.004 (-0.282)	0.017 (0.877)	0.020 (0.899)	-0.012 (-0.260)	-0.010 (-0.329)	-0.014 (-0.557)	0.062*** (2.943)	0.062* (1.904)	-0.008 (-0.462)	-0.008 (-0.462)	-0.003 (-0.165)	0.021 (1.187)
1.Ingroup × a _F	-0.004 (-0.052)	-0.053 (-1.179)	0.080*** (2.982)	-0.170 (-1.086)	0.029 (0.586)	-0.080*** (-2.670)	0.148** (2.071)	0.037 (0.494)	0.053 (0.313)	0.053 (0.313)	0.015 (0.201)	0.030 (0.489)
1.Ingroup × a _L × a _F	0.002 (1.002)	0.004** (2.415)	-0.003 (-1.589)	0.005** (2.278)		0.003 (1.219)	0.003 (1.333)	-0.000 (-0.089)	-0.007* (-1.881)	-0.007* (-1.881)	-0.000 (-0.099)	-0.001 (-0.760)
0.Common Fate × 1. Obs. Rituals	0.443** (2.268)	0.460 (1.314)	0.232 (0.838)	2.689*** (10.262)	4.242*** (3.971)	1.095 (0.989)	-0.038 (-0.073)	-1.628 (-1.573)	-0.891 (-0.609)	-0.891 (-0.609)	0.201 (1.085)	-0.713*** (-4.291)
1.Common Fate × 0. Obs. Rituals	0.349*** (3.884)	0.419* (1.939)	1.441*** (8.133)	2.747*** (9.799)	4.972*** (3.802)	-0.060 (-0.122)	0.128 (0.106)	-0.855** (-2.410)	-1.958** (-2.572)	-1.958** (-2.572)	-0.579** (-2.372)	-1.342*** (-2.687)
1.Common Fate × 1. Obs. Rituals	0.753*** (3.650)	-0.280 (-1.139)	-0.426 (-1.209)	0.822*** (4.151)	9.904*** (6.107)	0.879 (0.695)	-0.183 (-0.260)	-1.927*** (-3.138)	-0.791 (-1.267)	-0.791 (-1.267)	-0.188 (-0.470)	-1.276*** (-4.034)
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	.31	.37	.45	.58	.93	.27	.45	.79	.71	.35	.40	.36
N	520	550	520	200	170	170	190	210	210	210	350	350

Note: The numbers in parentheses are t-statistics from a logit regression with random effects and robust standard errors. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. The individual characteristics include age, age squared, gender, ethnicity Chinese, Catholic, Protestant, high income, middle income, language English, and social status (middle). In column (5) the interaction between Ingroup × a_L × a_F was excluded due to nonconvergence issues. In columns (6), (9), and (12) religion==protestant was excluded from due to nonconvergence.

Figure 3.9: Relationship between KSG and PSG

3.5.5 Do group specific social preferences explain group biases in knowledge sharing?

Lastly, we test whether prosocial games (PSG) embedded in the experiment have any spillover effect on the KSGs. First, we test the relationship between prosocial behavior and cooperative behavior in KSGs using a scatter plot. Figure 3.9 shows that prosocial behavior positively correlates with the KSGs. However, we must test if cultural inducements through the SIGs enhance knowledge sharing within groups directly or indirectly via the mechanism of enhanced group-specific preferences. For that, we conduct a series of mediation and moderation analyses on KSGs. Table 3.9 presents the mediating effects of PSGs on the relationship between cultural similarity and KSGs for the leader. We adopt generalized structural equation modeling to estimate PSG's mediating effects as our outcome variable; knowledge sharing decisions are binary. Column (1) presents the direct effects of the prosocial games in the presence of cultural similarity, common fate, and ritual dummies, while columns (2) to (6) show the indirect effect of PSGs on the relationship between cultural similarity and KSGs. Unlike in Table 3.8 column (1), cultural similarity from ingroup membership no longer becomes significant in Table 3.9 column (1) due to the mediating effects from KTG. Hence, the positive impact of cultural similarity on KSG is fully mediated by the prosocial behavior in KTG.

Although UG and DG do not have any mediating effects on cultural similarity, they directly affect leaders' knowledge sharing decisions. Tables 3.A.5 to 3.A.7 in Appendix A presents the mediation results for the alternative SIG classifications. Table 6A on low SIG performers show full mediating effects from UG and DG.

Table 3.9: Mediating effects of prosocial behavior on the leader's sharing decision- among high individual and group SIG scorers

	leader's knowledge sharing decision					
	Direct effect	Indirect Effect				
	Dep. Variable (1)	Mediator = UTG (2)	Mediator = KTG (3)	Mediator = NTG (4)	Mediator = UG (5)	Mediator = DG (6)
UTG	0.173 (0.726)					
KTG	1.370*** (4.362)					
NTG	0.389 (0.879)					
UG	0.494* (1.865)					
DG	1.741*** (7.034)					
Ingroup (CS)	0.094 (0.441)	1.002*** (5.137)	0.805*** (3.338)	0.461 (1.089)	0.101 (0.506)	0.279 (1.441)
Common fate	0.212 (0.912)	-0.137 (-0.641)	0.496* (1.776)	2.289** (2.326)	-0.288 (-1.216)	0.230 (1.154)
Obs. rituals	-0.099 (-0.442)	0.926*** (4.196)	0.213 (0.855)	1.074** (2.476)	0.652*** (2.967)	0.783*** (3.543)
Constant	1.435 (0.101)	-76.765*** (-5.299)	-67.085*** (-4.414)	-278.311*** (-5.811)	35.203*** (3.108)	-14.684 (-1.374)
Ind. controls	Yes	Yes	Yes	Yes	Yes	Yes
N	520	520	520	520	520	520

Note: The numbers in parentheses are t-statistics from a generalized structural equation model (GSEM) with robust standard errors. The link function for the GSEM is logit. The ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively. The individual controls include age, age squared, male, catholic, ethnic Chinese, middle income, and subject background applied sciences.

Next, we look at the mediating effects on the follower's knowledge sharing decisions. Table 3.10 presents the results. Columns (1) to (6) show the direct and indirect impact of PSGs on the follower's knowledge sharing decision when the leader shares. Columns (6) and (7) present UG's mediating effects on the follower's cooperative behavior when leader conceals. Although there are positive and significant direct effects from UTG, KTG, and UG on the followers' knowledge sharing decision (conditional on leader share), there appear to be no mediating effects from these prosocial behaviors as the cultural similarity variable is insignificant in columns (2), (3), and (5). However, cultural similarity loses its significance in the presence of their direct effects. Therefore, followers' cooperative

behavior appears to be driven by social preferences rather than cultural similarities when leaders choose to share knowledge.

If we look at UG's direct and indirect effects on followers' cooperative behavior conditioned on leader concealing knowledge, UG partially mediates the positive effect of cultural similarity on KSG. There is partial mediation from UG among low SIG performers as well (refer to Table 3.A.6).

Result 5.1: *Among high SIG performers, Kind Trust Game (KTG) fully mediates the positive effect of cultural similarity on leaders' knowledge sharing decision. Among low SIG performers, distributional concerns (e.g., in UG and DG) fully mediates positive effects of cultural similarity on leaders' knowledge sharing behavior.*

Result 5.2: *Prosocial behavior has no mediating effects on the follower knowledge sharing decision when leader shares knowledge. When leader conceals knowledge, Ultimatum Game (UG) partially mediates the positive effect of cultural similarity on followers' cooperative behavior. It is independent from SIG performance.*

Lastly, we look at the moderating effects of social preferences on the relationship between cultural similarity and KSG. To test the moderating effects, we include interactions between cultural similarity and PSGs in the regression models. Results are presented in Table 3.A.8. Although we observe some moderating effects from UG on leaders' knowledge-sharing decisions among high SIG performers, moderating effects of social preferences appears trivial.

Table 3.10: Mediating effects of prosocial behavior on the follower's sharing decision- among high individual and group SIG scorers

	Follower's decision conditional on leader sharing					Follower's decision conditional on leader conceal	
	Direct effect	Indirect Effect				Direct effect	Indirect Effect
	Dep. Variable (1)	Mediator variable =UTG (2)	Mediator variable =KTG (3)	Mediator variable =NTG (4)	Mediator variable =UG (5)	Dep. Variable (6)	Mediator variable =UG (7)
UTG	1.120*** (3.212)						
KTG	1.931*** (4.419)						
NTG	0.503 (1.361)						
UTG	1.120*** (3.212)						
UG	1.462*** (3.780)					1.795*** (5.728)	
Ingroup (CS)	0.250 (1.186)	-0.154 (-0.632)	-0.166 (-0.644)	0.896*** (3.392)	0.229 (0.758)	0.579*** (2.883)	0.390* (1.726)
Common fate	-0.255 (-1.145)	-0.131 (-0.434)	0.039 (0.129)	-0.236 (-0.859)	0.071 (0.224)	0.069 (0.315)	0.578** (2.351)
Obs. rituals	-0.447* (-1.833)	0.684** (2.463)	0.728*** (2.579)	0.308 (1.310)	0.896*** (3.305)	-1.006*** (-4.344)	-0.370 (-1.514)
Constant	-6.833 (-0.408)	29.447** (1.979)	5.358 (0.261)	-83.485*** (-4.332)	82.587*** (2.802)	70.422*** (4.012)	104.255*** (3.492)
Ind. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	550	550	550	550	550	550	550

Note: The numbers in parentheses are t-statistics from a generalized structural equation model (GSEM) with robust standard errors. The link function for the GSEM is logit. The ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively. The individual controls include age, age squared, male, catholic, ethnic Chinese, middle income, and subject background applied sciences. The table provide estimates for the individuals who have high SIG score coming from groups that have high group scores.

3.6 Discussion

In this paper, we investigate the role of cultural similarity on collaborative innovation. The first part of the study included an investigation that empirically tested the role of cultural similarity, IPR protection, and its interaction on bilateral patent collaborations using religion as a proxy for cultural similarity. We found that religious similarities promote bilateral technology innovation through trust, and its effects amplify under low IPR protection. To overcome the limitations in empirical analyses, we adopt an experimental approach to shed some behavioral insights to understand how cultural similarities affect individual strategic motives to cooperate during collaborative innovation. We create synthetic lab cultures by modeling *beliefs*, *fate*, *rituals*, and *common experiences*. While minimal groups, doomsday/paradise approaches are commonly used to model *beliefs* and *fate* in the experimental literature, no prior study have attempted to model rituals that resemble real cultural rituals or practices. The novelty of this paper is to introduce a non-incentivized social interaction game to model rituals. Participation in the ritual task was voluntary and costly (in terms of time and efforts), which signaled one's commitment to the group.

Key takeaways are as follows. First, we found that common fate and ritual manipulations mutually reinforce each other and jointly strengthen group identification. Secondly, social preferences for trust, trustworthiness, altruism, and tolerance were prominent among strong cultural manipulations. Thirdly, SIG performance profoundly affected leaders' and followers' cooperative behavior in the knowledge sharing game. Ingroup biases were salient for high performing leaders and followers in the SIG. However, ritual participation negatively affected ingroup favoritism among low SIG performers. Nonconformity to repetitive group tasks led to them exhibiting weak group effects. Fourthly, we found evidence for positive and negative discrimination towards ingroup and outgroup members. For instance, when the leader shares knowledge, intra-group competition lowered ingroup favoritism among high SIG performers, whereas when the leader concealed knowledge, the intragroup competition did not affect ingroup biases, thus creating positive discriminations for the follower. Minimal groups were sufficient to induce negative discrimination towards outgroup leaders. On the other hand, low SIG performers showed positive discrimination towards ingroup members. However, they appeared less discriminatory against outgroup members.

Fifth, our experimental evidence supports the notion that cultural similarity promotes collaborative innovation in environments with low IPR protection where trust is more required for fostering cooperation than in societies with strict IPR protection. Lastly, experimental results confirmed that prosocial behaviors have spillover effects on knowledge sharing decisions. For instance, social preferences in KTG and UG mediated the positive impact of cultural similarity on knowledge sharing behavior.

Overall, the study made two contributions at large to the literature. First, we introduced a novel non-incentivized social interaction game to induce ritual participation in laboratory experiments. Results confirm that SIG is crucial to the social identity creation process. High conformist individuals (in the SIG) were inclined to share knowledge with ingroup members exhibiting ingroup biases and this effect was more prominent among high conformist groups. Interestingly, low conformist individuals from low conforming groups showed ingroup biases in the KSG. In contrast, low conformists were more aggressive towards ingroup members in high conforming groups. Therefore, it is apparent that ingroup love is more salient when agents feel they are in the “same boat” rather than in “someone else’s boat”.

The second contribution is the practical implications for collaborative research organization. We show that cultural similarities between people signals shared values, norms, customs, and social behaviors, and these could spill over to encourage collaborative research within organizations. We could extend the social identity tools adopted in this paper to observe evolving cultural norms and trends and its implications. With new social norms emerging in the post Covid-19 world, experimenters can test the effectiveness of these social norms at reinforcing individual commitment, social preferences, and cooperative behaviors. It would be a promising direction for future research. In Addition, they can be extended to study diverse cultures.

3.7 Appendix A

Table 3.A.1: Core dimensions of different cultures

	Religion	Ethnicity	Ind-coll	Education	Language	Social Status	Political	National	Geography
Common Beliefs	×	×	×			×	×		
Common Fate	×								
Rituals	×	×		×		×	×	×	×
Common Experience	×	×	×			×	×		
Common Knowledge	×	×		×	×		×	×	×

Table 3.A.2: Robustness checks

Dependent = PCT applications	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
religious similarity	8.366*** (4.888)	7.291*** (4.806)	5.432*** (2.646)	5.660*** (2.712)	7.594*** (5.733)	7.814*** (5.235)	7.814*** (5.235)	7.814*** (5.235)	6.838*** (4.459)
religious similarity*IPR _{ij}	-0.860*** (-4.110)	-0.778*** (-4.385)	-0.532** (-2.185)	-0.558** (-2.220)	-0.791*** (-5.001)	-0.796*** (-4.316)	-0.796*** (-4.316)	-0.796*** (-4.316)	-0.686*** (-3.625)
IPR _{ij}	1.775*** (4.630)	2.382*** (6.222)	2.137*** (7.225)	2.061*** (7.030)	2.278*** (9.714)	1.313*** (4.233)	1.443*** (14.068)	1.032*** (7.093)	1.988*** (10.940)
Mean elevation _i	1.834*** (2.663)								
Mean elevation _j	-1.929*** (-6.820)								
Terrain roughness _i	-0.499*** (-5.633)								
Terrain roughness _j	0.885*** (7.443)								
Common religion		0.558** (2.277)							
Linguistic proximity			0.521** (2.204)						
Genetic proximity				-0.000*** (-3.616)					
Common legal origin					0.427*** (4.638)				
Ln(GDP per capita) _i						1.063*** (3.647)			
Ln(GDP per capita) _j						-1.140*** (-6.487)			
Ln(population) _i							0.800*** (9.050)		
Ln(population) _j							0.680*** (17.356)		
WTO member _i								3.620*** (3.528)	
WTO member _j								-3.199*** (-11.879)	
Patent stock _i									0.000*** (5.524)
Patent stock _j									0.000*** (4.094)
Constant	-9.209** (-2.291)	-12.350*** (-3.926)	-12.199*** (-4.315)	-11.433*** (-4.115)	-10.849*** (-5.916)	-3.614 (-1.436)	-10.672*** (-9.409)	-1.393 (-0.973)	-13.769*** (-9.503)
Baseline controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.984	0.984	0.984	0.986	0.988	0.943	0.944	0.984	0.985
N	1759	1879	1123	1123	1879	8508	4521	1879	1381

Note: The gravity model estimates are based on Poisson pseudo maximum likelihood estimation method. The numbers in parentheses are t-statistics based on robust standard errors clustered at the country level. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Dependent variable is the aggregate bilateral patent

collaborations between 2000 and 2016. This is based on all patents applications filed at the PCT (Source: OECD database) for technology classes ICT, nanotechnology, biotechnology, and environment-related technologies. Religious similarity data is based on religious fractions provided in the McCleary and Barro (2006) database. Data on IPR is from the Ginarte and Park (1997) database. Combined IPR protection (IPR_{ij}) is the sum of IPR protection in country i and country j . Data on bilateral geographic distance, contiguity, common language, common legal origin (after transition from colonial rule), colonial relationship, GDP per capita (in year 2000), population (in year 2000) and WTI membership are from CEPII database. Mean elevation and terrain ruggedness is from Ashraf and Galor (2011). Linguistic proximity is language proximity between any official language (Adserà and Pytlíková, 2015). Genetic proximity is from (Spolaore and Wacziarg, 2009). Patent stock is computed using the inventory perpetual method with 15% depreciation rate (Ang and Madsen, 2015).

Figure 3.A.1: Responsiveness in the ultimatum game between ingroup and outgroup members

Note: Followers reject unfair offers made by ingroup members more in *Gp.CF.Rt(obs)* treatment relative to other treatments with weak group identities. A possible reason could be that followers punish ingroup members more when unfair offers shatter positive expectations towards ingroup members induced by strong cultural identity.

Table 3.A.3: Expected payoffs, average payoffs, and mean sharing rates in DYG

Panel A: Leader sharing rate											
	Expected Payoff	Average Payoff	Overall sharing rate					Δ (in-out) group sharing rates			
			Gp.CF.Rt(obs)	Gp.IF.Rt(obs)	Gp.CF.Rt(ind)	Gp.IF.Rt(ind)	Baseline	Gp.CF.Rt(obs)	Gp.IF.Rt(obs)	Gp.CF.Rt(ind)	Gp.IF.Rt(ind)
KSG-1 ($a_L=0, a_F=0$)	20	20.81	0.56	0.64	0.67	0.61	0.56	0.06	0.03	-0.09	0.03
KSG-2 ($a_L=20, a_F=0$)	26.65	24.44	0.41	0.45	0.36	0.36	0.30	0.00	-0.28	0.03	0.03
KSG-3 ($a_L=0, a_F=20$)	20	16.63	0.55	0.52	0.58	0.58	0.52	0.03	0.09	-0.03	0.03
KSG-4 ($a_L=20, a_F=20$)	26.60	24.75	0.34	0.34	0.31	0.28	0.30	0.19	0.00	0.00	0.06
KSG-5 ($a_L=30, a_F=30$)	27.14	27.38	0.27	0.23	0.33	0.30	0.22	0.09	0.03	0.09	0.16
UTG	20	16.63	0.55	0.61	0.52	0.47	0.48	0.09	0.09	0.03	0.13
KTG	10	12.81	0.73	0.72	0.80	0.70	0.67	0.09	0.06	0.03	-0.03
NTG	10	12.19	0.89	0.81	0.84	0.83	0.88	0.09	0.00	0.00	0.03
UG	50	36.06	0.36	0.38	0.28	0.34	0.36	0.03	0.00	0.25	0.00
DG	50	43.94	0.38	0.30	0.34	0.22	0.28	0.00	-0.03	0.00	0.00
Panel B: Followers sharing rate contingent on Leader sharing											
	Expected Payoff	Average Payoff	Overall sharing rate					Δ (in-out) group sharing rates			
			Gp.CF.Rt(obs)	Gp.IF.Rt(obs)	Gp.CF.Rt(ind)	Gp.IF.Rt(ind)	Baseline	Gp.CF.Rt(obs)	Gp.IF.Rt(obs)	Gp.CF.Rt(ind)	Gp.IF.Rt(ind)
KSG-1 ($a_L=0, a_F=0$)	30	30.00	0.55	0.59	0.63	0.66	0.63	0.09	0.00	0.13	-0.06
KSG-2 ($a_L=20, a_F=0$)	30	30.00	0.45	0.64	0.67	0.56	0.64	0.09	0.16	0.09	0.25
KSG-3 ($a_L=0, a_F=20$)	50	45.81	0.14	0.30	0.20	0.22	0.19	-0.03	-0.03	0.16	0.06
KSG-4 ($a_L=20, a_F=20$)	50	45.87	0.16	0.25	0.20	0.25	0.17	-0.06	0.06	0.16	0.00
KSG-5 ($a_L=30, a_F=30$)	60	55.31	0.14	0.20	0.08	0.22	0.14	-0.03	0.09	0.03	0.00
UTG	50	46.53	0.17	0.25	0.16	0.23	0.23	-0.03	0.00	0.00	-0.09
KTG	50	45.81	0.09	0.11	0.09	0.20	0.08	-0.06	-0.03	-0.06	-0.03
NTG	50	45.88	0.13	0.23	0.19	0.27	0.22	0.00	0.03	0.06	0.03
UG	30	27.75	0.92	0.97	0.94	0.83	0.97	-0.03	0.06	0.00	-0.03
Panel C: Followers sharing rate contingent on Leader concealing											
	Expected Payoff	Average Payoff	Overall sharing rate					Δ (in-out) group sharing rates			
			Gp.CF.Rt(obs)	Gp.IF.Rt(obs)	Gp.CF.Rt(ind)	Gp.IF.Rt(ind)	Baseline	Gp.CF.Rt(obs)	Gp.IF.Rt(obs)	Gp.CF.Rt(ind)	Gp.IF.Rt(ind)
KSG-1 ($a_L=0, a_F=0$)	10	10.00	0.39	0.56	0.52	0.44	0.42	0.09	0.06	0.22	0.00
KSG-2 ($a_L=20, a_F=0$)	10	10.00	0.34	0.48	0.55	0.33	0.34	0.13	0.09	0.16	0.22
KSG-3 ($a_L=0, a_F=20$)	10	10.00	0.39	0.52	0.56	0.50	0.45	0.22	0.09	0.25	-0.06
KSG-4 ($a_L=20, a_F=20$)	10	10.00	0.42	0.48	0.56	0.53	0.44	0.16	0.09	0.25	0.13
KSG-5 ($a_L=30, a_F=30$)	10	10.00	0.38	0.50	0.58	0.45	0.39	0.13	-0.06	0.22	0.09
UG	10	7.94	0.80	0.80	0.80	0.78	0.80	0.03	0.16	0.09	-0.06

Figure 3.A.2: Alternative classification to observe ingroup and outgroup differences

Note: SIG-1 considers participants with high individual SIG scores (above median score) coming from groups that have performed above the median SIG group score. SIG-2 considers participants with low SIG scores from the high performing groups. SIG-3 include participants with high individual SIG scores coming from groups that have performed low in group SIG scores and SIG-4 includes those who have performed low in individual scores and well as group scores.

Figure 3.A.3: SIG group performance across treatments

Table 3.A.4: Marginal effects

Panel A: High individual SIG performance						
	High group performance			Low group performance		
	L_s	F_s/L_s	F_s/L_c	L_s	F_s/L_s	F_s/L_c
	(1)	(2)	(3)	(4)	(5)	(6)
Ingroup	0.077*** (3.644)	0.055** (2.105)	0.135*** (6.306)	0.030 (0.257)	-0.012 (-0.795)	0.047 (0.914)
a_L	-0.011*** (-7.994)	0.001 (1.014)	-0.002** (-2.360)	-0.012*** (-2.864)	-0.000 (-0.075)	-0.003*** (-4.172)
a_F	0.000 (0.267)	-0.018*** (-8.486)	0.003*** (18.242)	-0.004 (-0.957)	-0.017*** (-5.372)	0.002 (0.610)
Panel B: Low individual SIG performance						
	High group performance			Low group performance		
	L_s	F_s/L_s	L_s	F_s/L_s	L_s	F_s/L_s
Ingroup	-0.042 (-0.596)	0.114*** (4.755)	0.162** (2.399)	-0.006 (-0.230)	0.063 (0.943)	0.131 (1.250)
a_L	-0.017*** (-3.265)	-0.003*** (-8.266)	0.004*** (3.607)	-0.007* (-1.711)	-0.001*** (-3.127)	-0.000 (-0.051)
a_F	0.004 (0.965)	-0.009*** (-4.754)	-0.004 (-1.520)	-0.003 (-1.493)	-0.012*** (-10.631)	-0.001 (-0.609)

Note: The numbers in parentheses are t-statistics from a logit regression with random effects and robust standard errors. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 3.A.5: Mediation analysis for leader and follower for SIG=2 category

Panel A: leader's knowledge sharing decision						
	Direct effect	Indirect Effect				
	Dep. Variable	Mediator variable (KTG)	Mediator variable (NTG)	Mediator variable (UTG)	Mediator variable (UG)	Mediator variable (DG)
KTG	0.977* (1.857)					
NTG	0.662 (1.332)					
UTG	-0.898** (-2.228)					
UG	-0.140 (-0.326)					
DG	-1.189* (-1.888)					
Ingroup (CS)	-0.187 (-0.581)	-0.735* (-1.835)	-0.315 (-0.882)	-0.503 (-1.540)	0.844** (2.476)	-0.571 (-1.201)
Common fate	0.292 (0.571)	0.648 (1.272)	-0.029 (-0.067)	0.549 (1.271)	1.637*** (2.750)	1.201 (1.077)
Obs. rituals	-0.578 (-1.321)	-2.298*** (-5.033)	1.285*** (3.607)	-1.544*** (-3.632)	-0.421 (-0.980)	-1.781** (-2.035)
Constant	-99.704*** (-2.582)	- (-2.697)	50.867* (1.747)	- (-4.479)	-28.047 (-0.742)	-140.250*** (-2.637)
Ind. controls	Yes	Yes	Yes	Yes	Yes	Yes
N	200	200	200	200	200	200
Panel B: follower's decision conditional on leader sharing				Panel C: Follower's decision conditional on leader conceal		
	Direct effect	Indirect Effect			Direct effect	Indirect Effect
	Dep. Variable	Mediator variable (KTG)	Mediator variable (NTG)	Mediator variable (UTG)	Dep. Variable	Mediator variable (UG)
KTG	1.047 (1.547)					
NTG	1.024 (1.382)					
UTG	0.769 (1.416)					
UG					1.482** (2.399)	
Ingroup (CS)	0.872** (2.425)	-0.270 (-0.812)	-0.300 (-0.860)	-0.000 (-0.000)	0.895*** (2.740)	-0.554 (-1.199)
Common fate	-1.279*** (-2.978)	-1.556*** (-4.023)	-1.196*** (-3.042)	-0.965* (-1.797)	-1.380*** (-2.909)	-33.011*** (-31.092)
Obs. rituals	-0.368 (-1.021)	-0.781** (-2.335)	-0.831** (-2.335)	-1.131** (-2.111)	0.205 (0.562)	0.408 (0.624)
Constant	-1.299*** (-3.576)	-0.106 (-0.359)	-0.445 (-1.483)	-1.550*** (-3.868)	96.043** (2.555)	73.758 (0.903)
Ind. controls	No	No	No	No	Yes	Yes
N	210	210	210	210	210	210

Note: Due to GSEM non-convergence, individual controls and UG as a mediator variable was excluded.

Table 3.A.6: Mediation analysis for leader and follower for SIG=3 category

Panel A: leader's knowledge sharing decision						
	Direct effect	Indirect Effect				
	Dep. Variable	Mediator variable (KTG)	Mediator variable (NTG)	Mediator variable (UTG)	Mediator variable (UG)	Mediator variable (DG)
KTG	-0.416 (-0.885)					
NTG	-0.305 (-0.731)					
UTG	0.180 (0.502)					
UG	0.359 (1.116)					
DG	0.053 (0.158)					
Ingroup (CS)	0.107 (0.358)	0.476 (1.090)	0.349 (0.927)	0.483 (1.540)	0.428 (1.448)	-0.000 (-0.000)
Common fate	0.171 (0.560)	-0.715 (-1.629)	0.107 (0.284)	0.194 (0.619)	-0.516* (-1.728)	1.435*** (4.118)
Obs. rituals	-0.445 (-1.464)	0.715 (1.595)	-0.107 (-0.284)	0.290 (0.928)	-0.340 (-1.155)	-1.435*** (-4.118)
Constant	0.260 (0.412)	1.750*** (3.691)	1.399*** (3.659)	0.377 (1.248)	-0.214 (-0.757)	-0.883*** (-3.019)
Ind. controls	No	No	No	No	No	No
N	200	200	200	200	200	200

Note: Due to GSEM non-convergence, individual controls were excluded from the leader. Due to nonconvergence follower's mediation analysis was excluded. This could be due to the small sample size.

Table 3.A.7: Mediation analysis for leader and follower for SIG=4 category

Panel A: leader's knowledge sharing decision						
	Direct effect	Indirect Effect				
	Dep. Variable	Mediator variable (KTG)	Mediator variable (NTG)	Mediator variable (UTG)	Mediator variable (UG)	Mediator variable (DG)
KTG	1.022*** (3.326)					
NTG	0.244 (0.696)					
UTG	0.938*** (3.149)					
UG	0.676** (2.168)					
DG	0.817*** (2.937)					
Ingroup (CS)	-0.054 (-0.221)	0.000 (0.000)	0.499* (1.929)	0.000 (0.000)	0.647** (2.156)	-0.471* (-1.851)
Common fate	-0.016 (-0.058)	0.233 (0.916)	0.807*** (2.916)	-0.583** (-2.215)	-0.451 (-1.426)	0.821*** (2.979)
Obs. rituals	-0.389 (-1.439)	-0.370 (-1.428)	0.235 (0.901)	-0.022 (-0.088)	0.362 (1.125)	-0.229 (-0.790)
Constant	-57.138** (-2.167)	57.409** (2.326)	-26.900 (-1.228)	221.587** (6.821)	299.859** (8.166)	90.899*** (3.995)
Ind. controls	Yes	Yes	Yes	Yes	Yes	Yes
N	360	360	360	360	360	360

Panel B: follower's decision conditional on leader sharing						Panel C: Follower's decision conditional on leader conceal	
	Direct effect	Indirect Effect				Direct effect	Indirect Effect
	Dep. Variable	Mediator variable (KTG)	Mediator variable (NTG)	Mediator variable (UTG)	Mediator variable (UG)	Dep. Variable	Mediator variable (UG)
KTG	1.655*** (4.305)						
NTG	1.726*** (4.681)						
UTG	-0.219 (-0.452)						
UG	0.648 (1.002)					1.589*** (3.698)	
Ingroup (CS)	0.537* (1.930)	-0.344 (-1.371)	-0.000 (-0.000)	-1.037** (-2.413)	-0.571 (-1.355)	0.407* (1.695)	1.666*** (4.061)
Common fate	0.430 (1.135)	-1.533*** (-3.788)	-1.400*** (-4.688)	-2.793*** (-7.410)	2.721*** (3.078)	-0.772*** (-2.760)	-0.871 (-1.621)
Obs. rituals	-0.390 (-1.166)	1.948*** (4.203)	1.084*** (3.712)	0.758 (1.316)	0.695 (0.965)	0.011 (0.037)	-0.351 (-0.807)
Constant	-47.333** (-2.035)	-66.587*** (-3.607)	-19.276 (-1.011)	-88.188*** (-2.646)	333.758*** (4.601)	-23.267 (-1.445)	-26.180 (-0.884)
Ind. controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	350	350	350	350	350	350	350

Table 3.A.8: Moderating effects of prosocial behavior on the leader and follower's sharing decisions

	High individual SIG performance						Low individual SIG performance					
	High group performance SIG1			Low group performance SIG-3			High group performance SIG2			Low group performance- SIG4		
	L _s	F _s /L _s	F _s /L _c	L _s	F _s /L _s	F _s /L _c	L _s	F _s /L _s	F _s /L _c	L _s	F _s /L _s	F _s /L _c
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Ingroup	0.369 (1.465)	-0.083 (-0.102)	0.849*** (11.609)	2.679 (1.369)	-0.125 (-0.620)	0.512 (1.040)	-0.548** (-2.236)	1.119*** (3.872)	0.539* (1.814)	-0.338 (-1.371)	1.317* (1.835)	-0.960 (-1.530)
UTG	0.522 (1.270)	1.604 (1.472)		1.028** (2.380)	0.229 (0.689)		-0.980* (-1.906)	0.162 (0.124)		0.728 (1.325)	-0.944* (-1.874)	
KTG	1.294*** (3.263)	1.462** (2.396)		-0.208 (-0.914)	1.352*** (5.740)		2.053*** (3.194)	0.615 (0.963)		1.006** (2.316)	2.691*** (4.586)	
NTG	0.679* (1.899)	0.596 (0.712)		0.456** (2.179)	-0.457*** (-3.476)		-0.142 (-0.217)	2.150 (1.211)		0.270 (0.837)	1.677*** (10.952)	
UG	0.176 (0.605)	1.401* (1.793)	1.844*** (4.747)	0.114 (0.250)	0.000 (.)	2.039* (1.897)	-0.847** (-2.391)	1.020 (0.646)	1.526 (1.047)	0.474 (0.909)	0.491 (0.997)	1.233 (1.560)
DG	1.874*** (2.757)			0.365 (1.255)			-1.698** (-2.418)			1.087*** (6.233)		
Ingroup × UTG	-0.675 (-0.920)	-0.828 (-0.697)		-1.531* (-1.740)	0.000 (.)		0.284 (0.379)	-0.603 (-0.584)		0.352 (0.541)	0.713 (0.781)	
Ingroup × KTG	0.228 (0.598)	0.692 (1.298)		-1.436 (-0.890)	0.000 (.)		-1.598** (-2.059)	1.549 (1.180)		-0.120 (-0.156)	-1.933*** (-3.798)	
Ingroup × NTG	-0.252 (-0.492)	0.058 (0.094)		-0.257 (-0.214)	0.000 (.)		1.309*** (3.237)	-2.009* (-1.828)		0.256 (0.342)	0.158 (0.296)	
Ingroup × UG	0.576*** (5.200)	0.360 (0.418)	-0.294* (-1.647)	-0.170 (-0.224)	0.000 (.)	-0.375 (-0.836)	1.154 (1.604)	0.000 (.)	0.477 (1.294)	0.367 (0.598)	-0.395 (-0.493)	1.490*** (2.885)
Ingroup × DG	-0.183 (-0.539)			0.238 (0.355)			0.246 (0.175)			-0.289 (-0.413)		
Common Fate	-0.157 (-0.436)	-0.219*** (-2.595)	1.192*** (5.334)	0.389 (1.302)	-0.217*** (-10.890)	-0.497*** (-5.192)	0.661* (1.796)	-0.865** (-2.086)	-0.954 (-0.866)	0.521 (1.392)	0.538*** (2.875)	-1.096*** (-6.572)
Obs. Rituals	-0.318* (-1.783)	-0.443*** (-2.659)	0.063 (0.162)	0.895*** (5.082)	-0.396*** (-11.418)	-0.919** (-2.005)	-0.297 (-0.835)	-0.611** (-2.433)	0.657 (0.792)	0.154 (0.427)	-0.031 (-0.049)	-0.390 (-0.884)
Common Fate × Obs. Rituals	0.469 (1.599)	-0.055 (-0.967)	-2.125*** (-6.766)	-1.246*** (-5.739)	0.366*** (18.092)	0.676** (2.327)	-0.384* (-1.697)	0.126 (0.221)	-1.264 (-0.724)	-0.986** (-2.154)	-0.332 (-0.727)	0.627 (1.549)
Individual controls	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
R ²	.33	.32	.43	.24	.07	.18	.58	.48	.39	.31	.44	.35
N	520	550	520	200	155	170	190	210	210	360	350	350

Note: The numbers in parentheses are t-statistics from a logit regression with random effects and robust standard errors. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. The individual characteristics include age, age squared, gender, ethnicity Chinese, Catholic, Protestant, high income, middle income, language English, and social status (middle). In columns (8) and (9) we exclude individual controls to achieve convergence.

3.8 Appendix B

Experimental instructions- Gp.CF.Rt (obs) treatment

Welcome and thank you for participating in this experiment on decision making, organized by Nanyang Technological University. It is jointly funded by the NTU Start-Up Grant, and has been approved by the Ethics Committee of NTU. All the data from this experiment will be used only for research purposes. Your choices will not be linked to your personal identity, which will be kept private and confidential.

There are 8 participants in this **session**. The session can progress only if everyone does their tasks without interruption. It is therefore crucial that you continue your tasks in a timely manner without unnecessary delay. Please make sure you also have an uninterrupted internet connection. If you accidentally leave the webpage, please use the same link you were provided to enter the experiment and continue from where you left. The link will be active only until the end of the session. **Please do not close the browser or leave the session.** If you do so, we will not be able to pay you.

The session has three **stages**, in which there are a number of **rounds**, followed by a *questionnaire* and *payment*. All participants are given the same instructions throughout the session. Please read the instructions carefully, after which you will be asked to answer some questions to check if you have understood the tasks. If you have any questions, please send a **private message** to the experimenter and wait for further advice. To maintain the scientific integrity of the experiment, it is important that you follow these rules.

You will receive a participation fee of S\$5, and have the opportunity to earn more money in some stages of the experiment. You will receive your payment through “PayNow” after completion.

To enter the experiment, you are required to use a device with minimum 10-inch screen size. Please tick the checkbox to confirm the screen size.

☐ I confirm that my screen size is above 10-inches.

Please press “Next” to start the experiment.

Instructions for Stage 1

There are two color labels on the computer display: Yellow and Red. You need to state your preference between Yellow and Red. If you scroll towards the extreme left, it indicates an absolute preference for Yellow over Red. If you scroll towards the extreme right, it indicates an absolute preference for Red over Yellow. There is no “correct” answer. You can scroll the bar left or right to indicate your preference.

Press “Confirm” button to submit your choice. You must make your choice before you are allowed to move on to the next step.

The program has now collected the color preference values for all participants. The four participants with greatest preference for yellow are assigned to the **Yellow Group**. The four participants with greatest preference for red are assigned to the **Red Group**. Your computer screen tells you whether you belong to the Yellow Group or Red Group. **You will belong to the same color group throughout the experiment.**

Lottery: At the end of the experiment, computer will roll a virtual six-sided dice for each group, separately. If the randomly determined number is 6, each member of the group will receive a bonus of **S\$6**.

Yellow Group Dice
Bonus	0	0	0	0	0	S\$6

Red Group Dice
Bonus	0	0	0	0	0	S\$6

Control Questionnaire 1: Before you proceed, we ask that you answer a brief questionnaire for the purpose of checking whether you have understood the instructions for the lottery. Please press “Next” to view the control questionnaire 1.

Please press “Submit” when you have completed the questionnaire. You can only proceed to Stage 2 after you get all questions correct.

Control Questionnaire 1:

- How many people are there in each group?
 - 2
 - 4
 - 6
 - 8
- How will your earning change if the dice for your group lands on 2?
 - +\$6
 - \$6
 - +\$1
 - 0
- How will your earning change if the dice of your group lands on 6?
 - +\$6
 - \$6
 - 0
 - \$1
- When will the dice be rolled?
 - Beginning of experiment
 - At the end of each stage
 - Halfway through the experiment
 - End of experiment
- Which of the following statement is correct?
 - The same dice will be rolled for both groups.
 - Each group will have a dice, rolled separately.
 - None of the above.
- Which of the following statement is correct?
 - I will be paid a show-up fee of S\$5
 - I will be able to earn S\$6 from the lottery if the number drawn from the virtual dice land on 6
 - I have the opportunity to earn money from other stages apart from show-up fee and lottery
 - All of the above

Instructions for Stage 2

In this stage, you will perform the task in each round with the other three members of your group. There are 15 rounds in this stage, and 3 steps in each round.

Step 1: At the beginning of each round, you will have access to a **Codebook** of **Actions** and **Contexts** that is unique to your group

and different from the other group’s Codebook. Actions are presented across Rows and Contexts are presented across Columns. For each Context, there is one correct Action indicated by a tick (✓). A cross (×) indicates incorrect Actions for a given Context. Correct choices contribute to your **Group Score** in this stage.

Click on “View Codebook” button to see the Codebook; it will appear for 3 seconds per click. You are allowed a maximum 5 clicks per round. To enter the next step, please click “Continue” button. Once you click “Continue”, you cannot revisit the codebook. Figure 1 shows an example of a Codebook.

Figure 1

	Contexts	Context 1 (Location Pin)	Context 2 (Network)	Context 3 (Dice)	Context 4 (Target)
Actions		✓	×	×	×
		×	✓	×	×
		×	×	✓	×
		×	×	×	✓

Number of Views Left: 4

Buttons: View Codebook, Continue

Step 2: In this step, all members of the group will see a Context generated randomly by the computer. Next, you must choose the correct Action for the given Context. Confirm your choice within 10 seconds by pressing the “Confirm” button. You will know the choices of your group members for the round only after all members have made their choices. Figure 2 shows an example of a task.

Figure 2

Time left to complete this page: 5 seconds

Context: Location Pin

Please select your action by clicking on the button below it
If you wish to change your action, simply click on the one you wish to change to
Please click 'Confirm' after you are ready to proceed with your choice

Four stick figure icons with radio buttons below them.

Confirm button at the bottom left.

Step 3: Once you confirm your choice, the computer will show the actions chosen by all the members of your group and indicate whether each action was correct (✓) or incorrect (×). The computer will report the

number of ticks obtained by your group in that round (maximum 4 ticks per round) and the total number of ticks accumulated up to that round (maximum 60 ticks in the entire stage). Figure 3 shows the outcome.

Figure 3

To begin stage 2, please click “Proceed” button.

Instructions for Stage 3

In this stage, you will perform the task in each round with a coparticipant from your group *or* the other group. The coparticipant you are matched with is randomly determined in each round. The color of each participant’s group will be indicated by the color figures on the screen. There are 20 rounds in this stage.

In each task, one participant will choose first, followed by the other participant who will choose next. You will be randomly allocated the role of either **First Mover** or **Second Mover**. Your role will be stated at the top of your screen, and will remain the same throughout the stage. You will be paid for the experimental points that you have earned in one randomly determined round of this stage. Each point is worth S\$0.20. You will not know which round this is until the end of the experiment.

- In each round, you and your coparticipants have to choose between two actions A or B. You will not know the action chosen by your coparticipant.

Each participant will earn a number of points depending on the choices of both participants. These points are presented in **decision tables** and could change across rounds. It is therefore important to view the table anew in

each round. An example of a decision table for a First Mover is shown in Figure 1. For each combination of actions, points assigned to you will always appear **in bold and italics**.

How to read a decision table: Please refer to Figure 1 as an example.

How to make decisions:

If you are the First Mover, you must choose between A or B in each round. To choose an action, click on either button A or button B. Figure 1 shows an example of a task for a First Mover who belong to your group, paired with a Second Mover whose group color will be visible during the experiment.

If you are the Second Mover, you must choose between A or B for **each** of the two possible situations arising from the First Mover’s choice of A or B in each round, i.e. the Second Mover must make a choice for each of the two possible situations. Figure 2 shows an example of a task for a Second Mover who belongs to your group, paired with a First Mover whose group color will be visible during the experiment.

Control Questionnaire 2 – We ask you to answer a brief questionnaire for the purpose of checking whether you have understood the instructions in stage 3. Please press “Next” to view the control questionnaire 2.

Control Questionnaire 2

Please press, "submit" when you have completed the questionnaire. You can only proceed to Stage 3 after you get all questions correct.

Control Questionnaire for first mover:

1. Your role as First Mover or Second Mover remains the same throughout the stage.
 - a. True
 - b. False
2. If you are the First Mover, what are the choices available to you?
 - a. Choose between A or B
 - b. Choose between A or B when Second Mover has chosen A
 - c. Choose between A or B when Second Mover has chosen B
 - d. Both b and c are correct
3. If you are the Second Mover, what are the choices available to you?
 - a. Choose between A or B
 - b. Choose between A or B when First Mover has chosen A
 - c. Choose between A or B when First Mover has chosen B
 - d. Both b and c are correct
4. Which of the following statements are false?
 - a. I will be paid for the points I earn in every round
 - b. I will be paid for the points I earn in one round
 - c. I will not know which round I will be paid for until the end of the experiment
 - d. This round is randomly determined by the computer
 - e. The coparticipant I am matched with is randomly determined in each round
5. How much is 100 points worth in real money?
 - a. S\$10
 - b. S\$20
 - c. S\$30
 - d. S\$40

Control Questionnaire for second mover:

1. Your role as First Mover or Second Mover remains the same throughout the stage.
 - a. True
 - b. False
2. If you are the First Mover, what are the choices available to you?
 - a. Choose between A or B
 - b. Choose between A or B when Second Mover has chosen A
 - c. Choose between A or B when Second Mover has chosen B
 - d. Both b and c are correct
3. If you are the Second Mover, what are the choices available to you?
 - a. Choose between A or B
 - b. Choose between A or B when First Mover has chosen A
 - c. Choose between A or B when First Mover has chosen B
 - d. Both b and c are correct
4. Refer to the first decision table on the right. If the First Mover chose A you choose B, what is your payoff if the First Mover had chosen A?
 - a. 1
 - b. 2
 - c. 3
 - d. 4
5. Refer to the second decision table on the right. If the Second Mover chooses A after the First Mover had chosen B, what is the First Mover's payoff ?
 - a. 4
 - b. 5
 - c. 6
 - d. 7
6. Which of the following statements are false?
 - a. I will be paid for the points I earn in every round
 - b. I will be paid for the points I earn in one round
 - c. I will not know which round I will be paid for until the end of the experiment
 - d. This round is randomly determined by the computer
 - e. The coparticipant I am matched with is randomly determined in each round
7. How much is 100 points worth in real money?

- a. S\$10
- b. S\$20
- c. S\$30
- d. S\$40

Stage 4: Self-administered survey

Please fill in the information accordingly. Once completed please press submit.

Stage 5: Lottery

Now the computer will roll the respective dies for Yellow and Red groups, separately. Please wait until the randomly generated numbers appear on the screen.

Stage 6: Payment

Experimental instructions- Gp.IF.Rt (obs) treatment

Welcome and thank you for participating in this experiment on decision making, organized by Nanyang Technological University. It is jointly funded by the NTU Start-Up Grant, and has been approved by the Ethics Committee of NTU. All the data from this experiment will be used only for research purposes. Your choices will not be linked to your personal identity, which will be kept private and confidential.

There are 8 participants in this **session**. The session can progress only if everyone does their tasks without interruption. It is therefore crucial that you continue your tasks in a timely manner without unnecessary delay. Please make sure you also have an uninterrupted internet connection. If you accidentally leave the webpage, please use the same link you were provided to enter the experiment and continue from where you left. The link will be active only until the end of the session. **Please do not close the browser or leave the session.** If you do so, we will not be able to pay you.

The session has three **stages**, in which there are a number of **rounds**, followed by a *questionnaire* and *payment*. All participants are given the same instructions throughout the session. Please read the instructions carefully, after which you will be asked to answer some questions to check if you have understood the tasks. If you have any questions, please send a **private message** to the experimenter and

wait for further advice. To maintain the scientific integrity of the experiment, it is important that you follow these rules.

You will receive a participation fee of S\$5, and have the opportunity to earn more money in some stages of the experiment. You will receive your payment through “PayNow” after completion.

To enter the experiment, you are required to use a device with minimum 10-inch screen size. Please tick the checkbox to confirm the screen size.

☐ I confirm that my device screen size is above 10-inches.

Please press “Next” to start the experiment.

Instructions for Stage 1

There are two color labels on the computer display: Yellow and Red. You need to state your preference between Yellow and Red. If you scroll towards the extreme left, it indicates an absolute preference for Yellow over Red. If you scroll towards the extreme right, it indicates an absolute preference for Red over Yellow. There is no “correct” answer. You can scroll the bar left or right to indicate your preference.

Press “Confirm” button to submit your choice. You must make your choice before you are allowed to move on to the next step.

The program has now collected the color preference values for all participants. The four participants with greatest preference for yellow are assigned to the **Yellow Group**. The four participants with greatest preference for red are assigned to the **Red Group**. Your computer screen tells you whether you belong to the Yellow Group or Red Group. **You will belong to the same color group throughout the experiment.**

Lottery: At the end of the experiment, computer will roll a virtual six-sided dice for each of the participants, separately. If the randomly determined number is 6, you will receive a bonus of **S\$6**.

Individual Dice
Bonus	0	0	0	0	0	S\$6

Control Questionnaire 1: Before you proceed, we ask that you answer a brief questionnaire for the purpose of checking whether you have understood the instructions for the lottery. Please press “Next” to view the control questionnaire 1.

Please press “Submit” when you have completed the questionnaire. You can only proceed to Stage 2 after you get all questions correct.

Control Questionnaire 1:

- How many people are there in each group?
 - 2
 - 4
 - 6
 - 8
- How will your earning change if your dice lands on 2?
 - + \$6
 - \$6
 - + \$1
 - 0
- How will your earning change if your dice lands on 6?
 - + \$6
 - \$6
 - 0
 - \$1
- When will the dice be rolled?
 - Beginning of experiment
 - At the end of each stage
 - Halfway through the experiment
 - End of experiment
- Which of the following statement is correct?
 - The same dice will be rolled for both groups.
 - Each group will have a dice, rolled separately.
 - The same dice will be rolled for all participants in this stage.
 - Each participant will have a dice, rolled separately.
 - None of the above.
- Which of the following statement is correct?
 - I will be paid a show-up fee of S\$5

- I will be able to earn S\$6 from the lottery if the number drawn from the virtual dice land on 6
- I have the opportunity to earn money from other stages apart from show-up fee and lottery
- All of the above

Instructions for Stage 2- Same as Gp.CF.Rt(obs) treatment

Instructions for Stage 3- Same as Gp.CF.Rt(obs) treatment

Stage 4: Self-administered survey

Please fill in the information accordingly. Once completed please press submit.

Stage 5: Lottery

Now the computer will roll the respective dies for each participant, separately. Please wait until the randomly generated numbers appear on the screen.

Stage 6: Payment

Experimental instructions- Gp.CF.Rt(ind) treatment

Welcome and thank you for participating in this experiment on decision making, organized by Nanyang Technological University. It is jointly funded by the NTU Start-Up Grant, and has been approved by the Ethics Committee of NTU. All the data from this experiment will be used only for research purposes. Your choices will not be linked to your personal identity, which will be kept private and confidential.

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The session has three **stages**, in which there are a number of **rounds**, followed by a *questionnaire* and *payment*. All participants are given the same instructions throughout the session. Please read the instructions carefully, after which you will be asked to answer some questions to check if you have understood the tasks. If you have any questions, please send a **private message** to the experimenter and wait for further advice. To maintain the scientific integrity of the experiment, it is important that you follow these rules.

You will receive a participation fee of S\$5, and have the opportunity to earn more money in some stages of the experiment. You will receive your payment through “PayNow” after completion.

To enter the experiment, you are required to use a device with minimum 10-inch screen size. Please tick the checkbox to confirm the screen size.

☐ I confirm that my device screen size is above 10-inches.

Please press “Next” to start the experiment.

Instructions for Stage 1- Same as Gp.CF.Rt(obs) treatment

Instructions for Stage 2

In this stage, you will perform the task in each round individually. There are 15 rounds in this stage, and 3 *steps* in each round.

Step 1: At the beginning of each round, you will have access to a **Codebook** of **Actions** and **Contexts** that is unique to your group and different from the other group’s Codebook. Actions are presented across Rows and Contexts are presented across Columns. For each Context, there is one correct Action indicated by a tick (✓). A cross (×) indicates incorrect Actions for a given Context. Correct choices contribute to your **Individual Score** in this stage.

Click on “View Codebook” button to see the Codebook; it will appear for 3 seconds per click. You are allowed a maximum 5 clicks per round. To enter the next step, please click “Continue” button. Once you click “Continue”,

you cannot revisit the codebook. Figure 1 shows an example of a Codebook.

Figure 1

Actions	Contexts

	✓	×	×	×	×
	×	✓	×	×	×
	×	×	✓	×	×
	×	×	×	✓	×

Number of Views Left: 4
[View Codebook](#)
[Continue](#)

Step 2: In this step, all members of the group will see a Context generated randomly by the computer. Next, you must choose the correct Action for the given Context. Confirm your choice within 10 seconds by pressing the “Confirm” button. You will not know the choices of your group members for the round and they will not know the choice you made for the round. Figure 2 shows an example of a task.

Figure 2

Time left to complete this page: 5 seconds

Context

Please select your action by clicking on the button below it
 If you wish to change your action, simply click on the one you wish to change to
 Please click 'Confirm' after you are ready to proceed with your choice

☐ ☐ ☐ ☐

[Confirm](#)

Step 3: Once you confirm your choice, the computer will show the actions chosen by you and indicate whether it was correct (✓) or incorrect (×).The computer will report the total number of ticks accumulated up to that round (maximum 15 ticks in the entire stage). Figure 3 shows the outcome.

Figure 3

To begin stage 2, please click “Proceed” button.

Instructions for Stage 3- Same as Gp.CF.Rt(obs) treatment

Stage 4: Self-administered survey

Please fill in the information accordingly. Once completed please press submit.

Stage 5: Lottery

Now the computer will roll the respective dies for Yellow and Red groups separately. Please wait until the randomly generated numbers appear on the screen.

Stage 6: Payment

Experimental instructions- Gp.IF.Rt (ind) treatment

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until the end of the session. **Please do not close the browser or leave the session.** If you do so, we will not be able to pay you.

The session has three **stages**, in which there are a number of **rounds**, followed by a *questionnaire* and *payment*. All participants are given the same instructions throughout the session. Please read the instructions carefully, after which you will be asked to answer some questions to check if you have understood the tasks. If you have any questions, please send a **private message** to the experimenter and wait for further advice. To maintain the scientific integrity of the experiment, it is important that you follow these rules.

You will receive a participation fee of S\$5, and have the opportunity to earn more money in some stages of the experiment. You will receive your payment through “PayNow” after completion.

To enter the experiment, you are required to use a device with minimum 10-inch screen size. Please tick the checkbox to confirm the screen size.

☐ I confirm that my device screen size is above 10-inches.

Please press “Next” to start the experiment.

Instructions for Stage 1

There are two color labels on the computer display: Yellow and Red. You need to state your preference between Yellow and Red. If you scroll towards the extreme left, it indicates an absolute preference for Yellow over Red. If you scroll towards the extreme right, it indicates an absolute preference for Red over Yellow. There is no “correct” answer. You can scroll the bar left or right to indicate your preference.

Press “Confirm” button to submit your choice. You must make your choice before you are allowed to move on to the next step.

The program has now collected the color preference values for all participants. The four participants with greatest preference for yellow are assigned to the **Yellow Group**. The four participants with greatest preference

for red are assigned to the **Red Group**. Your computer screen tells you whether you belong to the Yellow Group or Red Group. **You will belong to the same color group throughout the experiment.**

Lottery: At the end of the experiment, computer will roll a virtual six-sided dice for each of the participants, separately. If the randomly determined number is 6, you will receive a bonus of **S\$6**.

Individual Dice
Bonus	0	0	0	0	0	S\$6

Control Questionnaire 1: Before you proceed, we ask that you answer a brief questionnaire for the purpose of checking whether you have understood the instructions for the lottery. Please press “Next” to view the control questionnaire 1.

Please press “Submit” when you have completed the questionnaire. You can only proceed to Stage 2 after you get all questions correct.

Control Questionnaire 1:

- How many people are there in each group?
 - 2
 - 4
 - 6
 - 8
- How will your earning change if your dice lands on 2?
 - + \$6
 - \$6
 - + \$1
 - 0
- How will your earning change if your dice lands on 6?
 - + \$6
 - \$6
 - 0
 - \$1
- When will the dice be rolled?
 - Beginning of experiment
 - At the end of each stage
 - Halfway through the experiment
 - End of experiment

- Which of the following statement is correct?
 - The same dice will be rolled for both groups.
 - Each group will have a dice, rolled separately.
 - The same dice will be rolled for all participants in this stage.
 - Each participant will have a dice, rolled separately.
 - None of the above.
- Which of the following statement is correct?
 - I will be paid a show-up fee of S\$5
 - I will be able to earn S\$6 from the lottery if the number drawn from the virtual dice land on 6
 - I have the opportunity to earn money from other stages apart from show-up fee and lottery
 - All of the above

Instructions for Stage 2

In this stage, you will perform the task in each round individually. There are 15 rounds in this stage, and 3 *steps* in each round.

Step 1: At the beginning of each round, you will have access to a **Codebook of Actions** and **Contexts** that is unique to your group and different from the other group’s Codebook. Actions are presented across Rows and Contexts are presented across Columns. For each Context, there is one correct Action indicated by a tick (✓). A cross (×) indicates incorrect Actions for a given Context. Correct choices contribute to your **Individual Score** in this stage.

Click on “View Codebook” button to see the Codebook; it will appear for 3 seconds per click. You are allowed a maximum 5 clicks per round. To enter the next step, please click “Continue” button. Once you click “Continue”, you cannot revisit the codebook. Figure 1 shows an example of a Codebook.

Figure 1

Actions	Contexts
	✓	×	×	×
	×	✓	×	×
	×	×	✓	×
	×	×	×	✓

Number of Views Left: 4

[View Contexts](#) [Continue](#)

Step 2: In this step, all members of the group will see a Context generated randomly by the computer. Next, you must choose the correct Action for the given Context. Confirm your choice within 10 seconds by pressing the “Confirm” button. You will not know the choices of your group members for the round and they will not know the choice you made for the round. Figure 2 shows an example of a task.

Figure 2

Time left to complete this page: 5 seconds

Context

Please select your action by clicking on the button below it.
If you wish to change your action, simply click on the one you wish to change to.
Please click 'Confirm' after you are ready to proceed with your choice.

☐ ☐ ☐ ☐

[Confirm](#)

Step 3: Once you confirm your choice, the computer will show the actions chosen by you and indicate whether it was correct (✓) or incorrect (×). The computer will report the total number of ticks accumulated up to that round (maximum 15 ticks in the entire stage). Figure 3 shows the outcome.

Figure 3

Context

Your Individual Score: 0 15

[Next](#)

To begin stage 2, please click “Proceed” button.

Instructions for Stage 3- Same as Gp.CF.Rt(obs) treatment

Stage 4: Self-administered survey

Please fill in the information accordingly. Once completed please press submit.

Stage 5: Lottery

Now the computer will roll the respective dies for each participant, separately. Please wait until the randomly generated numbers appear on the screen.

Stage 6: Payment

Experimental instructions- Baseline Treatment

Welcome and thank you for participating in this experiment on decision making, organized by Nanyang Technological University. It is jointly funded by the NTU Start-Up Grant, and has been approved by the Ethics Committee of NTU. All the data from this experiment will be used only for research purposes. Your choices will not be linked to your personal identity, which will be kept private and confidential.

There are 8 participants in this **session**. The session can progress only if everyone does their tasks without interruption. It is therefore crucial that you continue your tasks in a timely manner without unnecessary delay. Please make sure you also have an uninterrupted internet connection. If you accidentally leave the webpage, please use the same link you were provided to enter the experiment and continue from where you left. The link will be active only until the end of the session. **Please do not close the browser or leave the session.** If you do so, we will not be able to pay you.

The session has three **stages**, in which there are a number of **rounds**, followed by a *questionnaire* and *payment*. All participants are given the same instructions throughout the session. Please read the instructions carefully, after which you will be asked to answer some questions to check if you have understood the

tasks. If you have any questions, please send a **private message** to the experimenter and wait for further advice. To maintain the scientific integrity of the experiment, it is important that you follow these rules.

You will receive a participation fee of S\$5, and have the opportunity to earn more money in some stages of the experiment. You will receive your payment through “PayNow” after completion.

To enter the experiment, you are required to use a device with minimum 10-inch screen size. Please tick the checkbox to confirm the screen size.

☐ I confirm that my device screen size is above 10-inches.

Please press “Next” to start the experiment.

Instructions for Stage 1

Lottery: At the end of the experiment, computer will roll a virtual six-sided dice for each of the participants, separately. If the randomly determined number is 6, you will receive a bonus of **S\$6**.

Individual Dice
Bonus	0	0	0	0	0	S\$6

Control Questionnaire 1: Before you proceed, we ask that you answer a brief questionnaire for the purpose of checking whether you have understood the instructions for the lottery. Please press “Next” to view the control questionnaire 1.

Please press submit when you have completed the questionnaire. You can only proceed to Stage 2 after you get all questions correct.

Control Questionnaire 1:

- How many people are there in this session?
 - 2
 - 4
 - 6
 - 8
- How will your earning change if your dice lands on 2?

- + \$6
- \$6
- + \$1
- 0

- How will your earning change if your dice lands on 6?
 - + \$6
 - \$6
 - 0
 - \$1
- When will the dice be rolled?
 - Beginning of experiment
 - At the end of each stage
 - Halfway through the experiment
 - End of experiment
- Which of the following statement is correct?
 - The same dice will be rolled for all participants.
 - Each participant will have a dice, rolled separately.
 - None of the above.
- Which of the following statement is correct?
 - I will be paid a show-up fee of S\$5
 - I will be able to earn S\$6 from the lottery if the number drawn from the virtual dice land on 6
 - I have the opportunity to earn money from other stages apart from show-up fee and lottery
 - All of the above

Instructions for Stage 2

In this stage, you will perform the task in each round individually. There are 15 rounds in this stage, and 3 *steps* in each round.

Step 1: At the beginning of each round, you will have access to a **Codebook of Actions** and **Contexts** that is unique to you and different from other participants Codebooks. Actions are presented across Rows and Contexts are presented across Columns. For each Context, there is one correct Action indicated by a tick (✓). A cross (×) indicates incorrect Actions for a given Context. Correct choices contribute to your **Individual Score** in this stage.

Click on “View Codebook” button to see the Codebook; it will appear for 3 seconds per click. You are allowed a maximum 5 clicks per round. To enter the next step, please click “Continue” button. Once you click “Continue”,

you cannot revisit the codebook. Figure 1 shows an example of a Codebook.

Figure 1

Actions	Contexts				
		✓	×	×	×
		×	✓	×	×
		×	×	✓	×
		×	×	×	✓

Number of Views Left: 4

[View Codebook](#) [Continue](#)

Step 2: In this step, you will see a Context generated randomly by the computer. Next, you must choose the correct Action for the given Context. Confirm your choice within 10 seconds by pressing the “Confirm” button. Figure 2 shows an example of a task.

Figure 2

Step 3: Once you confirm your choice, the computer will show the action chosen by you and indicate whether it was correct (✓) or incorrect (×). The computer will report the total number of ticks accumulated up to that round (maximum 15 ticks in the entire stage). Figure 3 shows the outcome.

Figure 3

To begin stage 2, please click “Proceed” button.

Instructions for Stage 3

In this stage, you will perform the task in each round with another coparticipant from this session. The coparticipant you are matched with is randomly determined in each round. There are 20 rounds in this stage.

In each task, one participant will choose first, followed by the other participant who will choose next. You will be randomly allocated the role of either **First Mover** or **Second Mover**. Your role will be stated at the top of your screen, and will remain the same throughout the stage. You will be paid for the experimental points that you have earned in one randomly determined round of this stage. Each point is worth S\$0.20. You will not know which round this is until the end of the experiment.

- In each round, you and your coparticipants have to choose between two actions A or B. You will not know the action chosen by your coparticipant.

A

B

Each participant will earn a number of points depending on the choices of both participants. These points are presented in **decision tables** and could change across rounds. It is therefore important to view the table anew in each round. An example of a decision table for a First Mover is shown in Figure 1. For each combination of actions, points assigned to you will always appear **in bold and italics**.

How to read a decision table:

How to make decisions:

If you are the First Mover, you must choose between A or B in each round. To choose an action, click on either button A or button B. Figure 1 shows an example of a task for a First Mover, paired with a Second Mover.

If you are the Second Mover, you must choose between A or B for **each** of the two possible situations arising from the First Mover's choice of A or B in each round, i.e. the Second Mover must make a choice for each of the two possible situations. Figure 2 shows an example of a task for a Second Mover, paired with a First Mover.

The figure shows a screenshot of a computer interface for a game. At the top, it says "You are the second mover" and "Please click on your choice if your coparticipant has chosen A". Below this, there are two decision trees. The first tree shows a "Coparticipant" icon and a "You" icon. The "Coparticipant" has chosen A, and the "You" is choosing between A and B. The payoffs are 1, 2 for (A, A) and 3, 3 for (B, A). The second tree shows the "Coparticipant" has chosen B, and the "You" is choosing between A and B. The payoffs are 4, 5 for (A, B) and 6, 7 for (B, B). Below the second tree, it says "Please click on your choice if your coparticipant has chosen B".

Control Questionnaire 2 – We ask you to answer a brief questionnaire for the purpose of checking whether you have understood the instructions in stage 3. Please press “Next” to view the control questionnaire 2.

Control Questionnaire 2

Please press, “Submit” when you have completed the questionnaire. You can only proceed to Stage 3 after you get all questions correct.

Control Questionnaire for first mover:

1. Your role as First Mover or Second Mover remains the same throughout the stage.
 - a. True
 - b. False
2. If you are the First Mover, what are the choices available to you?
 - a. Choose between A or B
 - b. Choose between A or B when Second Mover has chosen A
 - c. Choose between A or B when Second Mover has chosen B
 - d. Both b and c are correct
3. If you are the Second Mover, what are the choices available to you?
 - a. Choose between A or B

- b. Choose between A or B when First Mover has chosen A
- c. Choose between A or B when First Mover has chosen B
- d. Both b and c are correct

4. Which of the following statements are false?
 - a. I will be paid for the points I earn in every round
 - b. I will be paid for the points I earn in one round
 - c. I will not know which round I will be paid for until the end of the experiment
 - d. This round is randomly determined by the computer
 - e. The coparticipant I am matched with is randomly determined in each round
5. How much is 100 points worth in real money?
 - a. S\$10
 - b. S\$20
 - c. S\$30
 - d. S\$40

Control Questionnaire for second mover:

1. Your role as First Mover or Second Mover remains the same throughout the stage.
 - a. True
 - b. False
2. If you are the First Mover, what are the choices available to you?
 - a. Choose between A or B
 - b. Choose between A or B when Second Mover has chosen A
 - c. Choose between A or B when Second Mover has chosen B
 - d. Both b and c are correct
3. If you are the Second Mover, what are the choices available to you?
 - a. Choose between A or B
 - b. Choose between A or B when First Mover has chosen A
 - c. Choose between A or B when First Mover has chosen B
 - d. Both b and c are correct
4. Refer to the first decision table on the right. If the First Mover chose A you choose B, what is your payoff if the First Mover had chosen A?
 - a. 1

- b. 2
 - c. 3
 - d. 4
- 5. Refer to the second decision table on the right. If the Second Mover chooses A after the First Mover had chosen B, what is the First Mover's payoff?
 - a. 4
 - b. 5
 - c. 6
 - d. 7
- 6. Which of the following statements are false?
 - a. I will be paid for the points I earn in every round
 - b. I will be paid for the points I earn in one round
 - c. I will not know which round I will be paid for until the end of the experiment
 - d. This round is randomly determined by the computer
 - e. The coparticipant I am matched with is randomly determined in each round
- 7. How much is 100 points worth in real money?
 - a. S\$10
 - b. S\$20
 - c. S\$30
 - d. S\$40

Stage 4: Self-administered survey

Please fill in the information accordingly. Once completed please press submit.

Stage 5: Lottery

Now the computer will roll the respective dies for each participant, separately. Please wait until the randomly generated numbers appear on the screen.

Stage 6: Payment

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