Journal of the Knowledge Economy
https://doi.org/10.1007/s13132-020-00626-4

ORIGINAL PAPER

Understanding Cultural Determinants of Scientific-Knowledge Development: Empirical Conceptualization from a Cross-Country Investigation

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Received: 27 October 2018 / Accepted: 6 January 2020/Published online: 11 January 2020

Abstract

The purpose of this paper is to test three hypotheses with regard to the development of scientific knowledge in relation to cultural dimensions. Two empirical models are formed to identify the causal effects of the cultural dimensions on scientific-knowledge development. The three hypotheses are tested in a case study consisting of 74 countries. Robust standard-error regressions are presented. The results show that the degree of egalitarian and hierarchical ethos across countries aids the growth of scientific knowledge. The empirical evidence complements new insights to the hypothesis of individualism-induced innovation. The evidence in this paper shows that the positive effect of individualism on the growth of scientific knowledge is also considerably lower than that of an egalitarian and hierarchical system. The proposition in this paper shows new insight into the economic and institutional evolution rooted in universal values of culture. As the world economy has been burdened by the enormous inequality of development, cultivating awareness of the competitive advantage hidden in cultural values is an essential prescription for advancing development policy pertaining to knowledge.

Keywords Cultural dimension · Egalitarianism · Hierarchy · Individualism · Innovation · Knowledge

Introduction

Development of scientific knowledge is instrumental in bringing about the means of industrial innovation (Mansfield 1995), thereby highlighting the evolutionary regimes most likely to achieve a society's chosen economic objectives and institutional quality.

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Knowledge based on research and development is also a chief support of economic growth according to the economic-growth literature (e.g., Romer 1986; Jones 1999). The focus of the current study is to identify factors that drive researchers' sheer determination to engage in scientific research and hence publications of scientific articles year after year. There is a growing concern regarding a number of universal cultural dimensions found significant for economic development based on cross-country case studies. The apparent one is individualism—Gorodnichenko and Roland (2011, 2017), Hansen (2013), and Williams and McGuire (2010) found a positive effect for this cultural dimension on economic prosperity in the United States (US) and other areas of the world. Nevertheless, effects of the cultural dimensions on the development of scientific knowledge have not been scrutinized by past studies. The absence of this investigation is a significant research gap because scientific knowledge is a chief determinant of economic development and institutional quality. Policy making requires detailed analyses and understandings of the causes of specific socioeconomic problems, as coined by the textbook knowledge in macroeconomics (Snowdon and Vane 2005, p. 7). This paper contributes to the literature by revealing the cultural dimensions—in comparison with the dimension of individualism—found to promote scientific development based on a multi-country case study.

This paper follows the concept of "collective mental programming" articulated by Hofstede (1980), considering the cultural characteristics at the societal level. This context is in line with the data characteristics used by the aforementioned literature with regard to individualism. Based on Gorodnichenko and Roland's (2011, 2017) study, individualism is theorized as a deeply rooted factor of economic growth, asserting it as a cultural drive that fosters innovation in exchange for monetary and social status rewards. Accordingly, Hansen (2013) shows that the second generation of US immigrants earns higher annual salaries owing to the US high degree of individualism. Furthermore, the degree of individualism also contributes to economic creativity according to Williams and McGuire (2010). Other cultural dimensions are either found less robust or with a negative effect. Nevertheless, the research gap in this paper implies that the findings of past studies cannot be generalized to the case of scientific-knowledge development. As scientific knowledge is a distinct development, its progression is hypothesized to be influenced differently by the cultural dimensions.

In the models, confounding issues are justified by the direct-vertical socialization theory (e.g., Bisin and Verdier 2000) while regarding culture as a difficult-to-change phenomenon amid the concept of collective mental programming (Hofstede 1980). This strategy treats culture as purely a long-term socialization of cultural characteristics from parents to children, and its effect on scientific-knowledge development is not influenced by environmental, institutional, and economic factors. This approach is consistent with Hansen's (2013) epidemiological approach in separating cultural effects from formal institutions. For ensuring empirical robustness, however, this paper also controls for the degree of human development as a possible confounder. Furthermore, the modeling design is consistent with the aggregating nature of the cultural data in terms of tracing the impact of cultural characteristics at the societal level, rather than of individuals (Hofstede 2001; Schwartz 2008). Correlations are generally low and medium among the independent variables and are hence not expected to distort the regression results.

The findings show a mix of positive and negative effects from seven cultural dimensions. Six are found to have a positive effect, including individualism. In particular, the hierarchy dimension, due to its emphasis on ensuring responsible and productive behaviors (Schwartz 2008), is found to be the most powerful factor of scientific-knowledge development in this multi-country case study. In contrast, the interaction of hierarchy and its polarized cultural dimension, egalitarianism, is found to have a negative effect on scientific-knowledge development. Because hierarchy has a long history in all countries, although differing by degree, understanding the influence of this cultural dimension on scientific-knowledge development is essential for policy makers looking to promote scientific knowledge for economic and institutional evolutions.

The remaining sections of this paper are as follows: empirical framework, results and discussions, and concluding remarks.

Empirical Framework

Knowledge economy incorporates intellectual aspects such as innovation and creativity, where knowledge serves as the root of growth in said aspects. Furthermore, Dubina et al. (2012) conceptualize the interrelation among knowledge, innovation, and creativity. In particular, they attribute "creativity economy" to be a new stage of economic development, whereas there is the possibility of economic crisis as innovation policy is inappropriate. Under this topic, economic creativity is examined by Williams and McGuire (2010) with respect to some cultural dimensions, namely, power distance, individualism, and uncertainty avoidance. Individualism is the one dimension that is critically ascertained to promote economic creativity. In line with that, further evidence is supplemented by Gorodnichenko and Roland (2011, 2017) who, in a cross-country investigation, propose an individualism-led growth hypothesis in which they argue that individuals' objective to pursue innovation is to gain social status rewards. This role of culture underpins the innovation–growth relationship, suggesting that cultural dimensions such as individualism have the intellectual behavior that foster innovation and economic creativity. However, the current study argues that innovation and economic creativity cannot grow without the growth of scientific knowledge. Thus, this paper aims to shed new insight on knowledge economy as conceptualized by Dubina et al. (2012); specifically, the growth of scientific publications is examined in relation to the cultural dimensions introduced by Hofstede (Hofstede 1980, 1993, 1994, 1999, 2001; Hofstede et al. 2010) and Schwartz (Schwartz 2008).

This paper investigates two models to determine the causal effects of 11 dimensions of national culture on scientific-knowledge development in a sample of 74 countries. The first model utilizes the cultural scores developed by Schwartz (2008) based on 56–57 items of the Schwartz value survey between 1988 and 2007. Each score is measured on a scale from −1 to 7 adjusted by a positive integer (4). This data set consists of four cultural pairs with seven cultural dimensions: (i) affective autonomy vs. embeddedness, (ii) intellectual autonomy vs. embeddedness, (iii) egalitarianism vs. hierarchy, and (iv) harmony vs. mastery. The baseline model equation comprises these cultural aspects:

$$\ln A_{it} = \alpha_0 + \alpha_1 T_i + \beta_j \sum_{j=1}^{J} C_{ji} + \phi_m \sum_{m=1}^{M} P_{mi} + \lambda L_i + \mu_{it}. \quad (1)$$

$\ln A_{it}$ in Eq. (1) is the degree of scientific-knowledge development. The dependent variable is represented by the number of technical and scientific journal articles measured as natural logarithmic seven-year averages from 2003 to 2016 (t = 2003–2009, 2010–2016). The data on the dependent variable are sourced from the National Science Foundation (n.d.). i is a cross-sectional unit (countries), T_i is a time dummy (T_i= 0 for 2003–2009, 1 for 2010–2016), C_{ji} is a Schwartz cultural dimension ($J = 7$), and P_{mi} is the interaction of two Schwartz cultural dimensions ($M = 4$). As explained in the following subsection, the degree of initial human capital development (L_i) is controlled in the model, and the data are the 2003 Human Development Index (HDI) sourced from the Human Development Reports of the United Nations Development Programme (n.d.). HDI is used as a measure of living standards in economics, particularly for studying global economic divergence (Snowdon and Vane 2005, pp. 580–583).

The other four dimensions of national culture are based on Hofstede's cultural dimensions theory (see Hofstede 1980): individualism, power distance, masculinity, and uncertainty avoidance. The data on the four cultural dimensions are sourced from the Hofstede Insights (n.d.) database, and the original references are made to Hofstede (2001) and Hofstede et al. (2010). Each dimension is measured on a 0–100 scale developed out of the employee value scores within the International Business Machine Corporation for the period 1967–1973. The baseline model equation is expanded by adding this set of cultural dimensions as explanatory variables:

$$\ln A_{it} = \alpha_0 + \alpha_1 T_i + \beta_j \sum_{j=1}^{J} C_{ji} + \phi_m \sum_{m=1}^{M} P_{mi} + \omega_k \sum_{k=1}^{K} H_{ki} + \lambda L_i + \mu_{it}, \qquad (2)$$

H_{ki} in Eq. (2) is a Hofstede cultural dimension ($K = 4$). One of the two model equations is to be selected based on a stronger Akaike information criterion (AIC) for interpreting the tests on the list of hypotheses presented in the following subsection with Table 1.

Without a priori knowledge of the functional form, a linear function is proposed as the default. The baseline model (Eq. 1) excludes Hofstede's four cultural dimensions and includes the four pairs of cultural dimensions introduced by Schwartz (2008), because these have not been explored as deeply as Hofstede's cultural dimensions. Why not include both Hofstede's and Schwartz's cultural dimensions? Fewer variables are definitely preferred for more ease of explanation of a model, as described by some studies as how the human mind works (Aragones et al. 2005; Wittgenstein 1922). Nevertheless, since previous studies have demonstrated the significance of some of Hofstede's cultural dimensions, an alternative specification is to include both sets of cultural dimensions, controlling for possible correlations between the two sets. How should a correct model be justified? This paper proposes a three-step postestimation procedure to identify one correct model between the two. First, the Breusch-Pagan test (Breusch and Pagan 1979) is performed to check for heteroskedasticity which is when the error variance is nonconstant and violates the best linear unbiased estimator of ordinary least squares (OLS), because the estimates would not have the minimum variance in the class of unbiased estimators; thus, in that case, a robust-variance estimator against heteroskedasticity should be computed using the "robust" command in Stata. Second, Ramsey regression specification-error test or RESET (Ramsey 1969) is computed to verify the model specification of linearity and no omitted-variable

Table 1 Hypotheses

Hypothesis 1	The following cultural dimensions are expected to have a positive effect on scientific-knowledge development: individualism, masculinity, hierarchy, egalitarianism, mastery, intellectual autonomy, and affective autonomy
Why are positive effects expected?	
Individualism	Being more individualistic motivates individual achievement (Hofstede 1980). Having the initiation to achieve something significant in research is essential for individual (social) scientists
Masculinity	Having a more masculine mind encourages competitiveness (Hofstede 1980). Masculinity provides individual researchers with the sheer will to continue demanding research tasks
Hierarchy	A hierarchical culture equips individuals with a mindset toward responsible and productive behavior (Schwartz 2008). Staying productive is a fundamental requirement for a researcher, thereby leading to more scientific publications
Egalitarianism	An egalitarian culture emphasizes moral equality and cooperation for all individuals (Schwartz 2008). As research development requires fair and cooperative behaviors among researchers, this culture is considered an essential factor of scientific-knowledge development
Mastery	Having a mastery mindset promotes self-assertion to attain group and individual goals by striving to master, direct, and change the natural and social environment (Schwartz 2008). This cultural orientation encourages individual researchers to look for novelty in research projects
Intellectual autonomy	Intellectual autonomy means individuals strive to achieve their own ideas and intellectual directions independently (Schwartz 2008). Thus, this is deemed a motivation for individual researchers to perform aggressively in scientific areas
Affective autonomy	Because affective autonomy induces individuals to pursue affectively positive experiences for themselves (Schwartz 2008), this could be a motivation for individual researchers to perform harder to satisfy their goals
Hypothesis 2	The following cultural dimensions are expected to have a negative or insignificant effect on scientific-knowledge development: power distance, uncertainty avoidance, harmony, and embeddedness
Why are negative effects expected?	
Power distance	Power distance implies an acceptance by individuals in terms of unequal distribution of social power in society (Hofstede 1980). This restricts an individual's freedom to challenge superiors' orders, which could limit creativity in research and development
Uncertainty avoidance	Uncertainty avoidance discourages individuals from undertaking risky tasks (Hofstede 1980). This culture diminishes the tendency to undertake research projects because of the risk of failure and time-consuming processes
Harmony	With harmonic culture, people tend to accept rather than direct and look for changes and exploitations (Schwartz 2008). As research development requires the sheer determination to change, direct, and exploit, this cultural dimension demeans the objective of scientific-knowledge development
Embeddedness	With embedded culture, people prefer to stay with the status quo and avoid actions that possibly distort in-group solidarity or traditions (Schwartz 2008). Maintaining the status quo is not conducive to scientific-knowledge development
Hypothesis 3	The following interactions of two cultural dimensions are expected to have a negative effect on scientific-knowledge development: affective autonomy vs. embeddedness, intellectual autonomy vs. embeddedness, egalitarianism vs. hierarchy, and harmony vs. mastery
Why are negative effects expected?	
	The interactions of two cultural dimensions mostly yield a negative effect on scientific-knowledge development because of the contrary characteristics

problem. In other words, RESET is a general test for examining the null hypothesis that a model is not misspecified (e.g., De Moraes et al. 2016; Gkouzos and Christofakis 2018). Omitted variables can give rise to endogeneity if correlation with the error term occurs. This is implemented using the "ovtest" command in Stata. Third, if both equations are variance-robust and without omitted variables, the next step is to select a model with the smallest Akaike information criterion (AIC) (Akaike 1973). The last step is implemented using the "est ic" command in Stata. In short, the correct model could be Eq. (1) or (2), which will be determined using the three-step statistical procedure introduced above.

Confounding Issues

To estimate the effect of cultural dimensions on scientific-knowledge development, the effects of extraneous variables that influence both independent and dependent variables must be suppressed. That said, cultural dimensions and scientific-knowledge development could be confounded by other variables (confounders) whenever the confounders have a causal effect on the said variables. However, this paper's theoretical proposition assumes that this confounding possibility is absent in the sense that cultural dimensions are a slow-moving phenomenon. Also, based on the previously mentioned studies (Hofstede 1980; Bisin and Verdier 2000), all cultural dimensions are treated as a direct-vertical socialization from our ancestry that is also collectively programmed within a country. Possible confounders, such as living standards, income per capita, and educational levels, only cause changes in the dependent variables. Because of this theoretical assumption, this paper controls for the level of HDI (comprising income per capita, educational levels, and life expectancy) in order to check the validity of the theoretical proposition. Together, the objective of this approach is to show that the direct causal effects from cultural dimensions on scientific-knowledge development are unbiased. In addition, because correlations among the cultural dimensions are generally low and intermediate, indicating the absence of significant distortion effects on the regression results.

Hypotheses

Using Eqs. (1) and (2), this paper tests three hypotheses. Table 1 presents brief descriptions for the designated hypotheses.

Cultural dimensions embody intellectual behaviors (e.g., individual initiation, eagerness to win, emotional independence), whereas culture is defined in anthropology as a socially transmitted information (Alvard 2003). To prove this argument, this paper proposes a model of scientific knowledge, and the cultural dimensions are examined as regressors to identify said intellectual behaviors. Cultural dimensions here are defined to be collective cultural behaviors of inhabitants at the country level, as introduced in the research by Hofstede. In Hofstede's (1980) technical terms, for example, these country-specific behaviors are referred to as collective mental programming in four dimensions: individualism, power distance, masculinity, and uncertainty avoidance. The possible intellectual behaviors embodied in these cultural dimensions are described in Table 1.

Indices of the cultural dimensions in Table 1 are composed using data collected from cross-country surveys in two researches led individually by Geert Hofstede and Shalom H. Schwartz. For example, individualism is one of the Hofstede's cultural dimensions measured on a 0–100 scale. For example, countries scoring higher in this cultural dimension, such as the US (score = 91/100), were identified from the US inhabitants who show characteristics emphasizing achievement, individual initiatives, leadership, and self-reliance, among others (Hofstede 1980, 2001; Hofstede et al. 2010). With these constructive characteristics, some studies have demonstrated evidence that this cultural dimension has a positive impact on innovation and economic growth (e.g., Gorodnichenko and Roland 2011, 2017; Williams and McGuire 2010), suggesting that collective human traits are validly captured by the cultural-dimension indices such as individualism and the others. Based on the description of each cultural dimension in the original research (Hofstede 1980, 1993, 1994, 1999, 2001; Hofstede et al. 2010; Schwartz 2008), this paper proposes three groups of hypotheses. Because the cultural dimensions have been ascertained by the past studies to indicate validly certain collective human traits, the hypotheses are expected to be able to examine correctly the relationship between the particular human traits measured by the cultural dimensions and the growth of scientific publications.

The scatterplot (Fig. 1) illustrates one example of the hypotheses stated in Table 1; the relationship between the degree of individualism and the number of scientific publications is plotted. Individualism is a benchmark in this paper because this cultural dimension has been popularized by past studies as a cultural determinant of innovation and economic growth (e.g., Gorodnichenko and Roland 2011, 2017; Williams and McGuire 2010). Individualism is measured on a 0–100 scale in the figure (0–25 = low; 26–50 = lower middle; 51–75 = upper middle; 76–100 = high). An increase in the degree of individualism is shown to have a positive association with the number of scientific publications, suggesting how an individualistic culture promotes the growth of scientific publications. However, one argument against this interpretation is that some low-individualism countries actually have grown their scientific publications as high as the high-individualism countries; for example, China's scientific publications are close to the US, but it is a low-individualism country (individualism score for China is 20/100). Other countries that exhibit this pattern include those in the lower-middle category, for example, Japan and India. Thus, why are those low-individualism countries as competitive as the high-individualism countries in terms of scientific publications? The answer is that the cross-country result is interpreted as a positive relationship between individualism and scientific publications. This interpretation is practically applicable for all specific countries regardless of being low or high in the cultural dimension. For instance, a one-score increase in individualism for China would foster more growth of scientific publications. This interpretation is an analogue of the case of economic-growth differences between developed and developing countries, where lower-income countries tend to have a higher annual growth rate than the developed countries. The plot indicates that some countries actually require a relatively low level of individualism to promote scientific research, while an increase in the degree of this cultural dimension would foster an even stronger outcome than the high-individualism countries. Effects of the other cultural dimensions can be interpreted using the same perception.

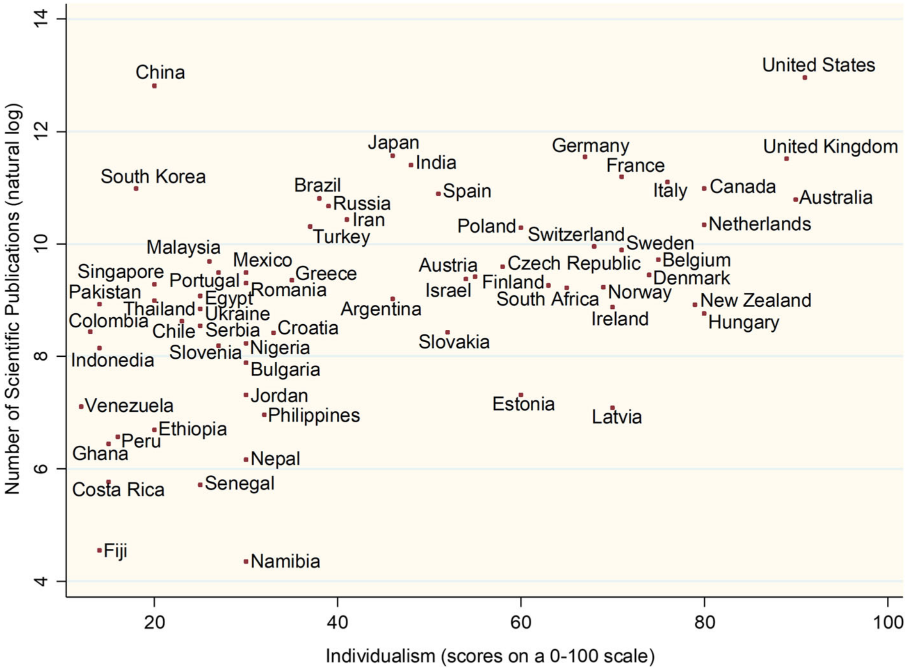

Fig. 1 Associating scientific-knowledge development (log of scientific publications) with individualism (scores on a 0–100 scale). The data on academic papers are from the National Science Foundation (n.d.) and the data on individualism are from Hofstede Insights (n.d.) (main references: Hofstede 2001; Hofstede et al. 2010)

Results and Discussions

Table 2 shows the regression results. Because heteroskedasticity is detected with the OLS estimator, a robust estimator is used for the two model equations. Heteroskedasticity, or nonconstant error variance, can be due to one or more factors. The presence of heteroskedasticity in this paper could be the result of skewness of data on four of the regressors; data skewness is commonly known to contribute to nonconstant error variance (Gujarati 2003, pp. 389–392). Another possibility, according to Gujarati, is an omitted-variable problem. However, the heteroskedasticity problem persists even after satisfying the omitted-variable problem detected by the Ramsey RESET statistic, suggesting the need for a robust estimator. All regressions are validated for model specification using the Ramsey RESET statistic—the statistic for Eq. (2) does not reject the null hypothesis that the function is not misspecified. Under the null hypothesis of Ramsey's (1969) regression specification-error test, or RESET, the general objective is to examine if a model is misspecified. Rejecting the null implies a misspecified model. Because this is a general test, the most common issue of model misspecification is omitted variables, which is also the null hypothesis programmed with the Stata "ovtest" command. The test uses the estimated dependent variable as additional regressor(s) in increasing power. If these additional regressors are statistical-

Table 2 Regression results for Eqs. (1) and (2) with robust standard errors

Dependent variable: scientific-knowledge development ($\ln A_{it}$)	Log-level regression for:		
	Equation (1)	Equation (2)	Equation (2.1)[a]
Explanatory variables			
Affective autonomy (C_{1i})	1.861 (6.017)	1.082 (5.854)	0.596 (5.867)
Intellectual autonomy (C_{2i})	−0.730 (8.495)	0.589 (8.276)	0.116 (8.066)
Embeddedness (C_{3i})	0.079 (5.958)	1.291 (7.090)	0.086 (6.188)
Egalitarianism (C_{4i})	0.821 (3.251)*	1.172 (3.041)***	1.263 (3.020)***
Hierarchy (C_{5i})	3.214 (6.926)**	4.417 (6.276)***	4.678 (6.202)***
Harmony(C_{6i})	1.481 (14.073)	1.099 (14.575)	0.902 (15.138)
Mastery (C_{7i})	0.874 (14.751)	0.746 (15.208)	0.621 (15.701)
Affective autonomy × embeddedness (P_{1i})	−1.000 (1.562)	−0.595 (1.551)	−0.312 (1.540)
Intellectual autonomy × embeddedness (P_{2i})	0.438 (2.338)	−0.327 (2.276)	−0.0002 (2.215)
Egalitarianism × hierarchy (P_{3i})	−2.564 (1.508)**	−3.614 (1.367)***	−3.886 (1.359)***
Harmony × mastery (P_{4i})	−1.341 (3.557)	−1.043 (3.680)	−0.935 (3.830)
Individualism (H_{1i})		0.541 (0.010)***	0.577 (0.010)***
Power distance (H_{2i})		0.304 (0.010)**	0.253 (0.009)**
Masculinity (H_{3i})		0.099 (0.006)*	0.113 (0.006)*
Uncertainty avoidance (H_{4i})		0.199 (0.010)*	0.170 (0.011)
HDI (L_i)	0.473 (2.239)***	0.345 (2.478)*	
Time dummy (2010–2016) (T_i)	0.119 (0.039)***	0.128 (0.044)***	0.128 (0.044)***
Intercept	−82.053 (64.459)	−97.805 (71.501)	−70.054 (70.345)
Groups (countries)	78	68	68
Observations	156	136	136
R-squared	0.56	0.64	0.617
Ramsey RESET statistic, null hypothesis: linear functional form	2.45 [0.066]	0.75 [0.524]	1.14 [0.335]
AIC	573.135	451.592	459.037

[a] Equation (2.1) is a variation of Eq. (2) for examining the robustness with confounders

Estimates for each explanatory variable are as standardized coefficients (standard errors). Values in square brackets are probability values. The symbols ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. The table reports 78 groups (in fact, 74 countries are reported in the text) because the Schwartz cultural data for the following countries are represented by two ancestral backgrounds: Canada (English and French), Israel (Arab and Jew), Germany (East and West), and Switzerland (German and French). Equation (2) uses fewer countries due to limitation of data on the Hofstede cultural dimensions ly significant, that suggests that some relevant variables have been omitted from the model. An alternative interpretation is given by Wooldridge (2010): a failure to reject the null hypothesis implies that the dependent variable is depending linearly on the regressors, hence, suggesting that the additional regressors are insignificant. These alternative interpretations are believed to be two complementary advantages for using the Ramsey RESET, as a statistical method for detecting an omitted-variable problem and/or incorrect functional form (e.g., De Moraes et al. 2016; Gkouzos and Christofakis 2018). Equation (2) also has a lower value of the Akaike information criterion and a higher coefficient of determination (R-squared), representing a better model of the two equations. Furthermore, statistical correlations among the cultural dimensions are low and intermediate; hence, statistical results are far from being significantly affected by strong correlations. The countries are represented regionally as follows: Africa (10), America (11), Asia (18), Europe (32), and Oceania (3).

The findings comprise a mix of positive and negative effects from seven cultural dimensions. Six are found to have a positive effect, including individualism. However, a hierarchical culture, due to its emphasis on ensuring responsible and productive behaviors (as highlighted in Table 1), is found to be the strongest factor that favors scientific development among the cultural dimensions studied in this paper. This is followed by the positive effect of egalitarianism. According to Schwartz's description, people in an egalitarian culture tend to cooperate and care about the welfare of other members in the society. In contrast, a hierarchical culture emphasizes responsible and productive behaviors in society. This could explain why the latter is found to have a stronger impact on scientific development in the two model equations.

Furthermore, the current study complements a new finding that the positive effect of individualism is half the effect of egalitarianism (standardized coefficient is 0.631 lower) and has a considerably lower effect than that of hierarchy (standardized coefficient is 3.876 lower). Furthermore, the current study complements a new finding that the positive effect of individualism is approximately half the effect of egalitarianism (standardized coefficient is 0.631 lower; obtained as 1.172−0.541) and has a considerably lower effect than that of hierarchy (standardized coefficient is 3.876 lower; obtained as 4.417−0.541). In other words, a one-standard-deviation increase in egalitarianism is associated with a 1.172 standard-deviation increase in the growth of scientific publications; this effect is 0.631 standard-deviation higher than the effect of individualism of a 0.541 standard-deviation increase in the growth of scientific publications. The effect of hierarchy is even stronger because the growth of scientific publications is shown by a 4.417 standard-deviation increase for a one-standard-deviation increase in the degree of hierarchy; this effect is 3.876 standard-deviation higher or about seven times the effect of individualism. The findings imply that the degree of productive and cooperative characteristics under an egalitarian and hierarchical system has a more impactful effect on scientific-knowledge development than the achievement-oriented effect of individualism.

The interaction of hierarchy and its polarized cultural dimension, egalitarianism, is found to have a negative effect on scientific development, revealing the degree of complexity of cultural forces related to processes of scientific development. A minor finding in the current study is that the masculinity, power distance, and uncertainty avoidance have relatively lower positive effects than individualism. Overall, 11 dimensions match the hypothesized causal effects highlighted in Table 1, although some are statistically insignificant. Furthermore, controlling for the degree of human development in the equations, as shown by the significant coefficient for HDI, does not significantly alter the statistical results for the cultural variables.

In summary, statistics indicate that not all countries with an enormous quantity of scientific publications are high in the degree of egalitarianism and hierarchy, whereas the implication of this paper is that an increase in these cultural dimensions can induce more scientific-knowledge development, thereby leading to more scientific and technical journal articles.

Robustness with Confounders

Given the theoretical assumption of exogeneity among the cultural variables, it is deemed necessary to examine the robustness of this assumption by controlling for possible confounders. This paper considers the degree of HDI that combines three possible confounding factors, namely, income per capita, educational levels, and life expectancy. The effect of HDI is found significantly positive on scientific-knowledge development, which implies the advantage of living standards in cultivating the development of scientific research. While the degree of human development is controlled, several cultural dimensions are significant with the expected hypothesized signs. This robustness check favors the theoretical assumption of exogenous and significant cultural effects, because removing the HDI variable does not render an apparent alteration to the overall results for the cultural variables—the results are presented as Eq. (2.1) in Table 2. However, the removal of HDI is not recommended for various reasons. The endogeneity problem is possible due to correlations between the cultural dimensions (regressors) and the error term, which is currently mitigated using the confounder. In particular, omitting HDI could cause some cultural dimensions to become insignificant as the effects of cultural dimensions on the growth of scientific publications are correlated with degree of human development embedded in the error term. For example, this paper re-estimates the models by removing the HDI variable (Eq. 2.1). The results show a slight reduction in the fitness of the regressions: First, the coefficient of determination (R-squared) is lower in Eq. (2.1) compared to the R-squared in Eq. (2). Second, the higher value of AIC for Eq. (2.1) suggests that Eq. (2) has a better fitness. Moreover, one cultural dimension (uncertainty avoidance) becomes insignificant when HDI is omitted, whereas this cultural dimension is significant at 10% critical level with the control of HDI in Eq. (2). Moreover, by comparing the standardized coefficients for the cultural dimensions between the last two columns, some differences can be observed with and without the HDI in the equation. Overall, the comparison implies that Eq. (2) is the selected model in this study.

Implications on Knowledge Economy and Economic Policies

Snowdon and Vane (2005, p. 634) assert that "Many social scientists would argue forcefully that the influence of culture should be added to the list of important deeper determinants of economic performance." Based on the results presented in Table 2, this paper justifies the significant value of considering cultural roles in economic development. As this paper's theoretical proposition suggests that culture is a slow-changing phenomenon, this assertion could be misperceived to mean that it is difficult to improve the cultural dimensions by economic policies. In such a situation, what kind of practical implications can be offered from the results of this paper? As presented in the diagram (Fig. 2), the standpoint of this paper is that economic development should adapt to local culture. The figure highlights the three cultural dimensions—hierarchy, egalitarianism, and individualism—found to support the hypotheses statistically. These cultural dimensions complement each other through several essential orientations articulated by Hofstede (1980) and Gorodnichenko and Roland (2011, 2017): productivity, cooperation, and initiative toward innovation. Scientific-knowledge development gains momentum from the three cultural orientations, which in turn boosts economic development. Economic development is not asserted to change culture; the figure implies that successful economic development should adapt locally based on policy makers' understanding of local culture because macroeconomic management is believed to depend on cultural limits:

> The culture of a country affects its parents and its children, teachers and students, labour union leaders and members, politicians and citizens, journalists and readers, managers and subordinates. Therefore management practices in a country are culturally dependent, and what works in one country does not necessarily work in another. However not only the managers are human and children of their culture; the management teachers, the people who wrote and still write theories and create management concepts, are also human and constrained by the cultural environment in which they grew up and which they know. Such theories and concepts cannot be applied in another country without further proof; if applicable at all, it is often only after considerable adaptation. (Hofstede 1994, p. 7)

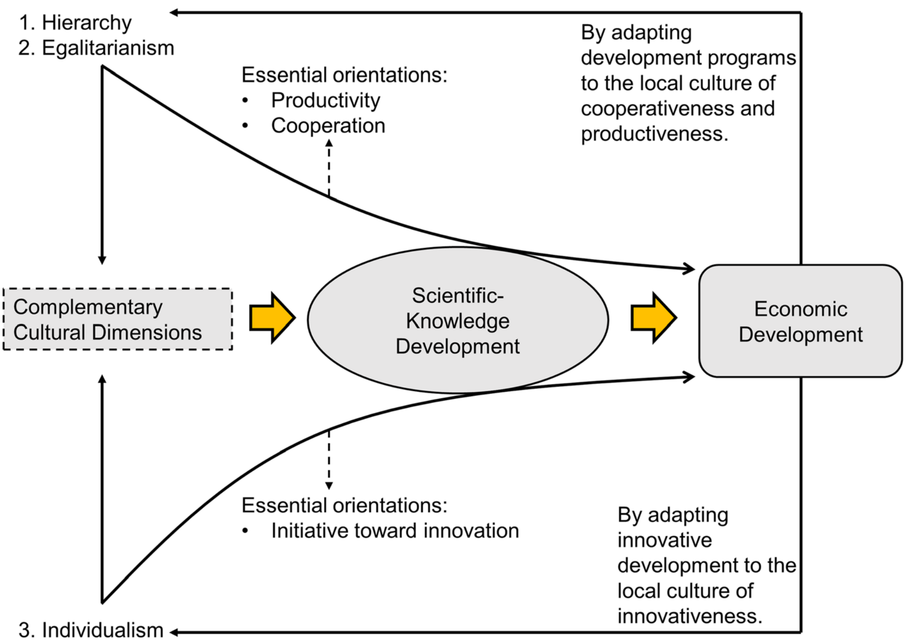

Fig. 2 Conceptualizing cultural behaviors and economic development

This study informs theory and policy based on a cross-country empirical framework or investigation, which follows a common practice of economic development studies such as Alesina et al. (2005, 2016), Easterly and Levine (1997), Gorodnichenko and Roland (2011, 2017), and Maurseth (2018), to name but a few. In line with the economic growth theory pioneered by Romer (1986), stock of knowledge is recognized as a factor that fosters economic prosperity, which is also a topic under knowledge economy. The findings of this paper shed light on the theory by showing evidence of new factors that contribute to the growth of scientific knowledge, particularly the growth of scientific publications and cultural dimensions, which is a topic that is unexplored in the literature. One knowledge informed by previous studies is the findings of collective human traits at the country level (Hofstede 1980, 1993, 1994, 1999, 2001; Hofstede et al. 2010; Schwartz 2008). Hofstede refers to these collective traits as the collective mental programming among inhabitants of a country. Macroeconomic policy is understood as a country-management policy (Snowdon and Vane 2005, p.1). According to Hofstede (1993), management policies need to recognize collective human behaviors that are known as cultural dimensions. Thus, the need to inform economic policy is to understand how country-level cultural dimensions influence the development of scientific knowledge, because validated and reliable knowledge is the core of successful management; the findings are deemed important to individual countries because each nation needs to consider the degree of collective cultural dimensions for developing an effective economic policy. For example, this paper finds that a one-standard-deviation increase in egalitarianism is associated with a 1.172 standard-deviation increase in the growth of scientific publications, which is 0.631standard-deviation higher than the effect of individualism. This finding implies that egalitarianism is twice as powerful as individualism in promoting scientific publications; this interpretation applies to specific countries. Furthermore, hierarchy is found to raise scientific publications by 4.417 standard-deviation for a one-standard-deviation increase in this cultural dimension. This effect is approximately four times (3.769) more powerful than egalitarianism and about eight times (8.165) more powerful than individualism. Previous studies inform theory and policy by showing evidence of individualism-led growth hypothesis with respect to innovation and creativity (e.g., Gorodnichenko and Roland 2011, 2017; Williams and McGuire 2010). The current study complements new findings in terms of egalitarianism-led growth and hierarchy-led growth evidence with respect to the growth of scientific knowledge. In addition to these findings, this paper also demonstrates significant, but smaller, benefits from power distance, masculinity, and uncertainty avoidance. For instance, a one-standard-deviation increase in the degree of power distance is associated with a 0.304 standard deviation increase in the growth of scientific publications. This effect is the result of eagerness of individuals to gain social power and distinguish themselves from others in terms of careers, social status, and material achievements. This effect is generally interpreted as the preference of society for social-power inequality (Hofstede 1980, 2001; Hofstede et al. 2010). In addition, this paper interprets the preference for social-power inequality to be the preference of individuals to escape neck-and-neck competition with others by pursuing excellence in scientific knowledge; for example, firms escape neck-and-neck competition with other incumbents by pursuing innovation (Aghion et al. 2001, 2005, 2009). Uncertainty avoidance raises the growth of scientific publications by 0.199 standard-deviation for a one-standard-deviation increase in this cultural dimension. This is interpreted to be the norm to avoid or reduce stress and anxiety by building the urge to work hard (Hofstede 1980). Scientific exploration is one way to meet this preference, hence, leading to more scientific publications per country. Lastly, masculinity is found with the least effect on the growth of scientific publications, where a one-standard-deviation increase in masculinity raises the growth in scientific publications by 0.99 standard deviation. According to Hofstede (1994), this cultural dimension puts stress on one's career. Thus, this effect can be interpreted as the urge of society to prove its ability in scientific knowledge through formal publications.

The development of scientific knowledge can concentrate in some regions in a country. However, prominent economic studies recognize that knowledge is virtually a public good (Arrow 1962; Jaffe 1989; Mankiw et al. 1995; Romer 1986) or as a nonrival commodity (Romer 1990). Therefore, knowledge can spread almost freely throughout a country. The knowledge diffusion can benefit the peripheral inhabitants because scientists or researchers need to collaborate with the local inhabitants for better research outcome, although some scientific fields could be more widespread and relevant than others. For instance, mathematical sciences may not collaborate with peripheral areas as much as social sciences, geology, and agricultural sciences. The outcome of scientific research could benefit peripheral inhabitants through knowledge diffusion, hence, fostering their awareness of socioeconomic development, in which it is only a matter of time before knowledge economy would find a way to those peripheral areas.

Research Limitations

As this paper investigates scientific-knowledge development based only on the number of journal articles, this reflects only the quantitative aspect. A more advanced approach is to use the explained variable weighted with the impact factor, because the qualitative aspect is also important in science-knowledge development. However, this paper is restricted by the considerable volume of scientific articles and fields to develop such a variable that is inclusive of both quantitative and qualitative information.

Secondly, as the data on the two sets of cultural dimensions were obtained originally using sample survey from different populations in the same set of countries, this could be a limitation to perform a direct comparison of the effects between the two sets of cultural variables. However, as described by Schwartz (2008), Hofstede (1980, 2001), and Hofstede et al. (2010), a general justification for this paper is that both sets of cultural data are based on sufficiently large samples to make the impression of national cultural dimensions, rendering a direct comparison possible.

Concluding Remarks

This paper has identified six cultural dimensions that could positively influence scientific development across countries. The key findings indicate the roles of the egalitarian and hierarchical ethos in ensuring scientific progress. In favor of the hypothesis that economic development can be fostered by the achievement-oriented characteristics of individualism, this paper suggests that scientific-knowledge development is nurtured by the degree of egalitarianism and hierarchy that favors responsibility, cooperation, and productivity. The two cultural dimensions are proven to have indirectly contributed to the evolutions of economic development and institutions via scientific-knowledge development.

The importance of this study is that it seeks to understand the creativity embedded in scientific publications in relation to some cultural dimensions and it is a topic that has not been demonstrated before in the literature. As Blaug (1991, pp. x–xi) explains, economic knowledge is not a one-time discovery, whereas it is an accumulation of all discoveries, false starts, and insights over a considerable period of time. Blaug's assertion should be legitimate to all fields of scientific research which are not particular to economics. Nevertheless, the knowledge that is unexplored up until now is the effects of collective human traits on the growth of scientific publications. According to the term popularized by Hofstede (1980) and his subsequent studies (Hofstede 1980, 1993, 1994, 1999, 2001; Hofstede et al. 2010), collective human traits are referred to as cultural dimensions at the country level. This study is expected to shed new light on knowledge economy because some of the cultural dimensions have been ascertained by previous studies to be important to innovation and economic growth, particularly Gorodnichenko and Roland (2011, 2017) and Williams and McGuire (2010). Because scientific knowledge is the pathway of economic efficiency, such as the growth of science observed during the late-1800s in Europe following the age of the Industrial Revolution (Persson and Sharp 2015), identifying new determinants of the growth of scientific publications is, therefore, important. Furthermore, understanding what cultural dimensions actually promote new scientific knowledge is an important contribution to the improvement of socioeconomic policies. Economic policy makers refer to economic theories as a policy guideline, but economic theories do not work universally, thereby the argument here is that past studies have not considered the importance of cultural dimensions. For instance, according to Hofstede (1993), "In fact, the management theorist who ventures outside his or her own country into other parts of the world is like Alice in Wonderland." Thus, why do cross-country cultural dimensions matter in this paper? Hofstede's (1980) study has the answer; collective behaviors of inhabitants or cultural mental programming (also known as collective mental programing or cultural dimensions) are distinguishable at the country level. That said, could economic divergence observed across the world be explained by differences in the effects of cultural dimensions on the growth of scientific knowledge? Because economic divergence is beyond the scope of this paper, the focus here is on the relationship between cultural dimensions and the growth of scientific publications. Covi (2016) asserts that divergence of economic growth is beyond physical capital, whereas technical and organizational knowledge, learning ability, and the human capital are far more important. These three aspects are examined by the current study as the relationship between cultural dimensions and scientific publications. The rationale of choosing the dependent variable is also based on the fact that scientific publications are the most universally recognized channel to distribute scientific knowledge throughout the world.

Acknowledgments The author is grateful to the anonymous reviewers and journal editors for their time and constructive comments. The data that support the findings of this study are publicly available from the sources cited in the text and reference list.

Compliance with Ethical Standards

Competing Interests The author declares that there are no financial and/or non-financial competing interests.

References

Aghion, P., Harris, C., Howitt, P., & Vickers, J. (2001). Competition, imitation and growth with step-by-step innovation. *Review of Economic Studies, 68*(3), 467–492.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., & Howitt, P. (2005). Competition and innovation: An inverted-U relationship. *Quarterly Journal of Economics, 120*(2), 701–728.

Aghion, P., Blundell, R., Griffith, R., Howitt, P., & Prantl, S. (2009). The effects of entry on incumbent innovation and productivity. *Review of Economics and Statistics, 91*(1), 20–32.

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. In B. N. Petrov & F. Csaki (Eds.), *Second international symposium on information theory* (pp. 267–281). Budapest: Akailseoniai–Kiudo.

Alesina, A., Spolaore, E., & Wacziarg, R. (2005). Trade, growth and the size of countries. *Handbook of Economic Growth, 1*(B), 1499–1542.

Alesina, A., Harnoss, J., & Rapoport, H. (2016). Birthplace diversity and economic prosperity. *Journal of Economic Growth, 21*(2), 101–138.

Alvard, M. S. (2003). The adaptive nature of culture. *Evolutionary Anthropology: Issues, News, and Reviews, 12*(3), 136–149.

Aragones, E., Gilboa, I., Postlewaite, A., & Schmeidler, D. (2005). Fact-free learning. *American Economic Review, 95*(5), 1355–1368.

Arrow, K. J. (1962). The economic implications of learning by doing. *Review of Economic Studies, 29*(3), 155–173.

Bisin, A., & Verdier, T. (2000). "Beyond the melting pot": Cultural transmission, marriage, and the evolution of ethnic and religious traits. *Quarterly Journal of Economics, 115*(3), 955–988.

Blaug, M. (1991). *The historiography of economics*. Aldershot and Brookfield: Edward Elgar.

Breusch, T. S., & Pagan, A. R. (1979). A simple test for heteroscedasticity and random coefficient variation. *Econometrica, 47*(5), 1287–1294.

Covi, G. (2016). Local systems' strategies copying with globalization: Collective local entrepreneurship. *Journal of the Knowledge Economy, 7*(2), 513–525.

De Moraes, C. O., Montes, G. C., & Antunes, J. A. P. (2016). How does capital regulation react to monetary policy? New evidence on the risk-taking channel. *Economic Modelling, 56*, 177–186.

Dubina, I. N., Carayannis, E. G., & Campbell, D. F. J. (2012). Creativity economy and a crisis of the economy? Coevolution of knowledge, innovation, and creativity, and of the knowledge economy and knowledge society. *Journal of the Knowledge Economy, 3*(1), 1–24.

Easterly, W., & Levine, R. (1997). Africa's growth tragedy: Policies and ethnic divisions. *Quarterly Journal of Economics, 112*(4), 1203–1250.

Gkouzos, A., & Christofakis, M. (2018). Multiplier effects under a disaggregate economic base model. *Journal of Economic Studies, 45*(2), 383–400.

Gorodnichenko, Y., & Roland, G. (2011). Which dimensions of culture matter for long-run growth? *American Economic Review, 101*(3), 492–498.

Gorodnichenko, Y., & Roland, G. (2017). Culture, institutions, and the wealth of nations. *Review of Economics and Statistics, 99*(3), 402–416.

Gujarati, D. N. (2003). *Basic econometrics*. NY: McGraw-Hill.

Hansen, C. W. (2013). Economic growth and individualism: The role of informal institutions. *Economics Letters, 118*(2), 378–380.

Hofstede Insights. (n.d.). Intercultural management: Compare countries. https://www.hofstede-insights.com/product/compare-countries/. Accessed 2 Jul 2018.

Hofstede, G. (1980). Motivation, leadership, and organization: Do American theories apply abroad? *Organizational Dynamics, 9*(1), 42–63.
Hofstede, G. (1993). Cultural constraints in management theories. *Academy of Management Executive, 7*(1), 81–94.
Hofstede, G. (1994). The business of international business is culture. *International Business Review, 3*(1), 1–14.
Hofstede, G. (1999). Problems remain, but theories will change: The universal and the specific in 21st-century global management. *Organizational Dynamics, 27*(1), 34–44.
Hofstede, G. (2001). *Culture's consequences: Comparing values, behaviors, institutions, and organizations across nations*. Thousand Oaks: Sage Publications.
Hofstede, G., Hofstede, G. J., & Minkov, M. (2010). *Cultures and organizations: Software of the mind*. New York: McGraw-Hill.
Jaffe, A. B. (1989). Real effects of academic research. *American Economic Review, 79*(5), 957–970.
Jones, C. I. (1999). Growth: With or without scale effects? *American Economic Review, 89*(2), 139–144.
Mankiw, N., Phelps, E., & Romer, P. (1995). The growth of nations. *Brookings Papers on Economic Activity, 1995*(1), 275–326.
Mansfield, E. (1995). Academic research underlying industrial innovations: Sources, characteristics, and financing. *Review of Economics and Statistics, 77*(1), 55–65.
Maurseth, P. B. (2018). The effect of the internet on economic growth: Counter-evidence from cross-country panel data. *Economics Letters, 172*, 74–77.
National Science Foundation. (n.d.). Science and engineering indicators: Scientific and Technical Journal Articles. World Bank: World Development Indicators. https://databank.worldbank.org/source/world-development-indicators . Accessed 7 Oct 2018.
Persson, K. G., & Sharp, P. (2015). *An economic history of Europe. Knowledge, institutions and growth, 600 to the present*. Cambridge: Cambridge University Press.
Ramsey, J. B. (1969). Tests for specification errors in classical linear least-squares regression analysis. *Journal of the Royal Statistical Society, 31*(2), 350–371.
Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy, 94*(5), 1002–1037.
Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy, 98*(5), S71–S102.
Schwartz, S. H. (2008). The 7 Schwartz cultural value orientation scores for 80 countries. ResearchGate. https://www.researchgate.net/publication/304715744_The_7_Schwartz_cultural_value_orientation_scores_for_80_countries. Accessed 2 July 2018. https://doi.org/10.13140/RG.2.1.3313.3040
Snowdon, B., & Vane, H. R. (2005). *Modern macroeconomics: Its origins, development and current state*. Cornwall: Edward Elgar Publishing Limited.
United Nations Development Programme. (n.d.). Human development reports, human development data (1990-2017): Human development index. http://hdr.undp.org/en/data . Accessed 7 Oct 2018.
Williams, L. K., & McGuire, S. J. (2010). Economic creativity and innovation implementation: The entrepreneurial drivers of growth? Evidence from 63 countries. *Small Business Economics, 34*(4), 391–412.
Wittgenstein, L. (1922). *Tractatus logico-philosophicus*. London: Routledge 1961 reprint.
Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MA: MIT press.