Cultural correlates of national innovative capacity: a cross-national analysis of national culture and innovation rates

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Abstract

Although it is conventional wisdom that innovation requires free mind, diversity, or creativity all of which are closely associated with political and organizational decentralization, it is in fact more politically centralized countries in East Asia that successfully capitalized on innovation to catapult their economies onto the growth trajectory. Scholars have thus wondered if this is an exception rather a rule. Are more centralized countries innovative? Existing empirical research has produced mixed results. This study introduces a new perspective on this issue. Rather than the degree of centralization found in formal institutions, we focus on non-institutional or informal dimensions of centralization particularly associated with culture. Using Hofstede's cross-national dataset capturing national culture, we explore how different dimensions of national culture are linked to national innovative capacity as proxied by patents. Our preliminary findings from the analysis of 34 OECD member states based on the patent data extracted from the Patent Cooperation Treaty (PCT) database suggest that non-institutional dimensions of centralization account more for the variations in national rates of patents per capita than more formal aspects of centralization measured by traditional political datasets such as POLCON. While cultural aspects have been examined in technology management at the individual and the firm level, this study fills a gap in the existing literature by exploring their relationship at the national level. More research is clearly needed to explore the roles of non-institutional features facilitating or hampering innovation.

Keywords: Authoritarianism, Culture, Democracy, Decentralization, Development, Innovation, Patent, Technology

Introduction

Are politically decentralized countries more innovative? Since technological innovation prospers upon creativity, which in turn hinges on a free-thinking mind, one may well expect more democratic countries allowing greater individual freedom to provide a better institutional environment for technological innovation, as exemplified by Silicon Valley in the US, one of the most politically de-centralized countries. By the same token, more authoritarian countries with greater restriction on individual freedom would be less propitious for innovation.

Yet the development experience of East Asian countries that grew rapidly under strongly centralized political authorities over the last few decades indicates that such

Jang *et al. Journal of Open Innovation: Technology, Market, and Complexity* (2016) 2:23

Page 2 of 16

conventional wisdom may be half true. Japan, the archetype of the developmental state, as well as the Asian tigers (South Korea, Hong Kong, Singapore, and Taiwan) all accomplished fast-track modernization backed by technological innovation under more or less authoritarian political regimes.

Some might criticize their technology-driven development was essentially based on reverse engineering rather than true technological breakthroughs. Yet it is still the case that not all countries succeeded in applying and improving upon borrowed technologies for their economic take-off. One cannot downplay the significance and importance of learning by doing during the technological catch-up process if one notes that many developing countries of similar levels of development to that of the Asian tigers at the beginning of the latter's take-off still remain where they were.

It is thus natural to ask why innovations are hard to come by in more authoritarian countries but some relatively authoritarian countries still manage to develop upon technological innovation despite the conventional linkages of innovation and de-centralization.

Political correlates of technological innovation

While early discussions of political correlates of technological innovation can be found in the works of classical political economists such as Adam Smith and David Ricardo, contemporary explorations of political factors and institutions underpinning technological innovation date back to the studies of Joseph Schumpeter and Michal Kalecki. Schumpeter's well-known Mark I and Mark II innovations imply different types of organizations and political dynamics resulting from them (Schumpeter, 1962; 2003). Mark I innovation is close to current-day innovation thinking in business management, characterized by numerous small entities interacting with one another for cost-reducing innovation under almost perfect competition. Such interactions would be best promoted by decentralized organizations, whether political or economic. In contrast, Mart II innovation means bigger and more fundamental changes in the existing technology enabling a near-monopoly position. As such it has close affinity with big businesses as well as more centralized forms of planning and control (Malerba & Orsenigo, 1995).

In his widely cited work, Kalecki (1943, 1968) analyzed the political motivations of financial and industrial elites who oppose full employment secured by government spending, and verified the role of public investment for innovation. Courvisanos (2009) reinterpreted that innovation and R&D activities over a business cycle are strongly connected with political decisions such as public investment, following Kalecki's work.

Political explanations on innovation also include the studies with specific geographic focus, such as the case studies of Central and Eastern European Countries (CEECs). Svarc (2006) and Nikolova (2007) analyzed the political change regarding the success and failure of national innovation systems (NIS) in Croatia and Bulgaria, attributing the differences in NIS to their ability to adapt to change from the socialism to free-market economy. Because most countries in this region have experienced similar economic difficulty during the transition from the communist to democratic regimes, their experiences have great implications for countries in East Asia which are, generally speaking, socially authoritarian and politically centralized.

Jang *et al. Journal of Open Innovation: Technology, Market, and Complexity* (2016) 2:23

Page 3 of 16

Meanwhile, some scholars have explored more explicitly the mechanisms underlying the linkage between political decentralization and innovation. Taylor (2007) summarized the linkages of decentralization and innovation into four mechanisms, focusing on the effects of vertical decentralization (Lijphart, 1999).[1] Firstly, vertical decentralization of power from central to local governments tend to increase the number of actors performing as well as participating in R&D activities. This proliferation of stakeholders in the national R&D system helps to multiply technological experimental efforts. Secondly, as in the Delaware Effect, the increase of political unit leads to higher competition for investment or other resources among them, which should in turn encourage greater innovation to attract more investment (Cary, 1974; Oates, 1972). Thirdly, local governments have greater and better information and knowledge on local conditions than remote central governments, which would lead to innovations that reflect better local preferences and constraints (Hayek, 1945; Tiebout, 1956). As an example, with the same amount of R&D money, some states may use it to advance basic research, while others use it to fund more practical initiatives. Finally, under decentralized governance, it is hard for interest groups to capture bureaucracies, as there are more veto players in the political system. Technological innovation would be facilitated more in decentralized systems more resistant to capture by vested interests (Weingast, 1995).[2]

Despite such conjectures on the positive linkage of political decentralization and technological innovation, Taylor's empirical investigation of the national innovation rates has shown very little evidence for them. Whether measured with the number of scientific publications, patents, or high-tech exports, decentralized countries were no more or no less innovative than centralized countries.

Adding the cultural dimension

In this study, we revisit the linkage of decentralization and innovation by looking more closely into the cultural dimension. The existing studies reviewed above have largely confined themselves to "institutional" variables that are manifest in the form of hardware such as organizations and other entities. While an institution also includes norms, rules, and expectations (North, 1990; Garrido, 2014), not much attention has been paid to those less organizational, more software-like aspects of the institution when it comes to institutional factors underlying national innovation capacity.

Our study starts with a simple hunch that the mixed empirical evidence for the linkage of political decentralization and innovation might be due to the influence of non-institutional aspects of decentralization such as cultural attributes. In other words, not only political decentralization but cultural decentralization may matter for technological innovation, as creativity, ingenuity, or originality underpinning innovative activities would prosper more in culturally less authoritarian environments. Even in politically decentralized countries, individuals may experience a culturally stifling atmosphere that discourages them from venturing with novel ideas.

In order to examine the cultural dimension of technological innovation, we have relied on the cross-national measures of culture devised by Geert Hofstede's (1980; 1988; 2001), which have been widely used in the field of multicultural psychology and other areas applying the notion of national culture (Gales, 2008). Originally derived from the IBM's project comparing how people solve a problem, collaborate with each

Jang *et al. Journal of Open Innovation: Technology, Market, and Complexity* (2016) 2:23

Page 4 of 16

other, and treat their supervisors in different countries in the 1960 ~ 70s, Hofstede's measures have evolved into six dimensions of the following: Power Distance Index, Individualism as contrasted to Collectivism, Masculinity as contrasted to Femininity, Uncertainty Avoidance Index, Long-Term Orientation as opposed to Short Term Orientation or Pragmatism, and Indulgence as opposed to Restraint.[3] More detail on each dimension is provided in the next section.

In a recent study, Taylor & Wilson (2012) have conducted a similar analysis to our own, examining the correlations between national culture and innovative capacity with Hofstede's measures (House et al., 2004; Schwartz, 2006). Their study focused largely on individualism, which was founded to have a positive effect on innovation in most countries.[4] It is one of the very few studies that examine the linkage of cultural traits and national innovation rates, which can be improved further in a couple of aspects.

Firstly, it would be important and interesting to examine not only individualism but other dimensions of national culture captured in Hofstede's measures, for these other dimensions may as well correlate with the tendencies for innovation. For instance, societies with greater long-term orientation are more likely to support activities that bear fruit in the long run. Also, in a culture with a greater tendency to avoid uncertainty, individuals, firms, or public organizations would be less encouraged to undertake risky projects. Secondly, though Taylor & Wilson's work was published in 2012, the data that they used are somewhat outdated. For instance, the data for the patents and papers used in this study are for the years of 1970s ~ 90s, which are almost two decades apart from now.

In our study, we have updated the data beyond the time period of Taylor & Wilson's study. As their study data cover the years till 1995, we employ the data for 15 years between 1996 and 2012. The end year of 2012 is chosen because the latest POLCON data are available for 2012.

We also added more cultural variables than those used in their study in order to explore the effects of multiple dimensions of national culture on national innovative capacity. Since the patent data are more reliable for advanced countries, we have limited our empirical analysis to OECD member states. In particular, by examining the effects of all six dimensions of Hofstede's cultural model, we have tried to uncover the cultural correlates of national innovative capacity. With this examination, we hope to find whether non-institutional aspects of decentralization as embodied in cultural values have significant effects on the national levels of technological innovation. Figure 1 shows simply our research framework.

Meanwhile, the cultural dimensions of innovation correlate deeply with the principle of open innovation which is defined as 'the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and to expand the markets for external use of innovation, respectively' (Chesbrough et al. 2006).

The scholarly literatures on open innovation have revealed the importance of creating a favorable climate for innovation-friendly organization (Kanter, 1983; Ekvall, 1996; Isaksen & Tidd, 2006; Yusr, 2016). Notable among them is the comparison with closed innovation principle (Chesbrough, 2003b; West & Gallagher, 2006; Santoro & Chakrabarti, 2001; Nakamura et al. 1997). Closed organizations are generally tend to ignore critical ideas of outsiders based upon dogmatic conviction on their superiority with monopoly of knowledge, which lead to the phenomenon such as 'Not Invented Here (NIH)' (Katz &

Fig. 1 Research framework
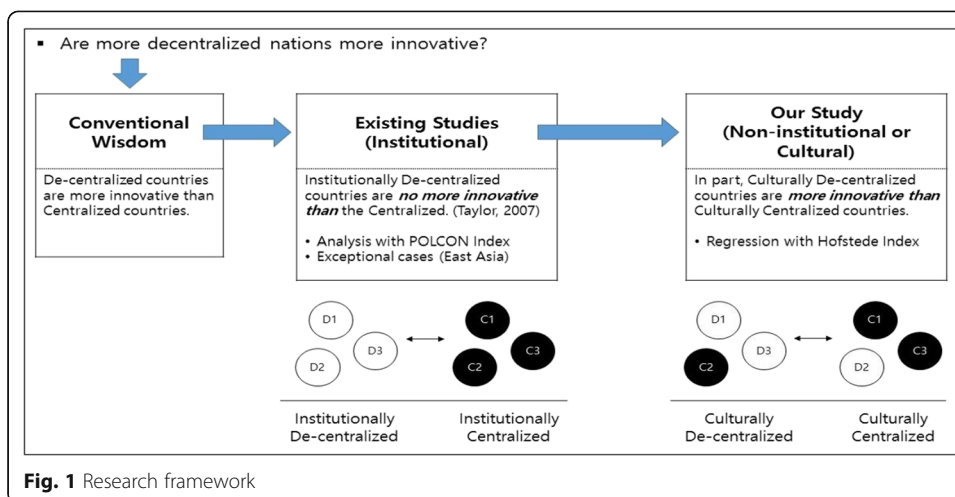
Allen, 1982). Open culture valuing the external sources of know-how and competences is one of the pillars of open innovation (Gassmann et al. 2010). In firm-level, it has been pointed out that cultural gaps between partnering corporates hinder their collaborations. Han van der Meer (2007) reports how Dutch entrepreneurs accepted the principle of open innovation and changed their corporate culture toward open-friendly one. Dodgson et al. (2006) describes the challenges Procter & Gamble faced while pursuing open innovation strategy called 'Connect and Develop (C&D)' through 1999 to 2005, when it had to change its 'autarkic approach and high-level supervision culture for new product development' to open culture. The company officials interviewed said that P&G had to go through deep cultural change in the process. Vareska van de Vrande et al. (2009) refer to cultural difference between corporates as the greatest challenge SMEs face pursuing open innovation in Netherlands.

Although these studies mostly focused on a corporate-level analysis, such principle of open innovation is well known for its significant implications for national innovative capacity and NIS (Jeon et al. 2015; Chesbrough, 2003a). In national level, Nho (2016) describes in-depth how Korea-specific research ethics has negative impact on open innovation, with detailed summary on common characteristics underlying the East Asian cultures. Furthermore, in the light of history of civilizations, Carrillo (2015) indicates further the 'cultural evolution' from nomad hunting-gathering through agricultural and industrialized to modern knowledge-based societies as a crucial factor for development of open innovation principle.

Data and method

Our primary task in this empirical analysis is to explore the effect of cultural factors on national innovative capacity. National innovative capacity can be defined as a country's potential to generate innovations, which depends on a host of conditions ranging from the level of economic and technological sophistication to political institutions and policy choices (Furman, et al. 2002).

In operationalizing national innovative capacity, we follow the previous studies by drawing on the patent data. There exist more comprehensive measures of national innovative capacity such as the World Competitiveness Scoreboard of International Institute for Management Development (IMD), and Global Competitiveness Index of

Jang *et al. Journal of Open Innovation: Technology, Market, and Complexity* (2016) 2:23

Page 6 of 16

World Economic Forum (WEF). Yet we have decided to rely on the patent data as they have been used in many academic studies and would therefore allow comparisons of our findings with those of the previous ones. Our patent data come from the OECD's 2012 Patent Statistics, and the number of the patent applications filed to the Patent Cooperation Treaty (PCT) per 100,000 residents is used as the dependent variable.

We are particularly interested in the relative effects of institutional vs. non-institutional aspects of decentralization, with the former largely measured by the well-known measure of political constraint and the latter proxied by Hofstede's cultural variables as described in detail below.

For the institutional dimension of decentralization, we draw on the Political Constraint Index (POLCON) from the Political Constraint dataset developed by Witold Henisz (2000), which incorporates Tsebelis' veto point index. POLCON, scaled from zero to one, measures the feasibility of policy change – that is, how flexibly a policy can be changed in the process of balancing political powers between different political apparatuses. It was created out of almost ninety categories reflecting various administrative, legislative and judicial characteristics such as the presence of a well-functioning legislature, different levels of court, local government autonomy, and an alignment between the executive and the legislative chambers. There are two versions of the index – POLCON III and POLCON V. POLCON III is created based on the separation of power between executive and legislative branches, while POLCON V includes the judiciary and local governments as additional veto points. Our analysis uses both versions, though we will draw more on POLCON V.

Turning to non-institutional dimensions of decentralization, we utilize Hofstede's six measures of national culture as follows. First, the power distance index (PDI) captures the degree of societal hierarchy such as inequality and authoritarian relations among individuals. Second, individualism (IDV) captures the prevalence of individualistic (ego-centric) attitudes as compared to collectivistic (socio-centric) attitudes. Third, masculinity (MAS) indicates the degree to which a society is driven more by task orientation emphasizing competition and achievement rather than by person orientation as caring for others, cooperation, or quality of life. Fourth, the uncertainty avoidance index (UAI) captures the degree of preference for more orthodox behavior and traditional conventions, or in other words, aversion of the ambiguous and unknown situations.

These four measures were the original set of indicators Hofstede developed out of his IMB studies. With further case studies, he refined his measures by adding the following two dimensions. One is the long-term orientation (LTO), which captures the degree to which a society values long-term perspective such as planning for the future and perseverance for goal attainment. The other is indulgence (IND), which indicates the degree to which a society allows individuals to seek freely the gratification of their desires and needs so as to have fun and enjoy life.

These three sets of the variables – PCT patents as the dependent variable, POLCON as the independent variable capturing the institutional dimension of decentralization, and Hofstede's measures as the independent variable capturing the cultural dimension of decentralization – constitute the variables of major interest in this study.

We have also controlled for a number of factors influencing national innovation capacity, following Taylor & Wilson's study. These are: per capita GDP, gross R&D expenditure, military spending, trade openness, fuel exports, and educational spending.[5] Table 1 shows the descriptive statistics of the variables included in our analysis.

Table 1 Summary statistics

Major Variables	Obs.	Mean	Std. Dev.	Min	Max
Patents (per 100,000 people)	34	9.43	8.29	0.14	28.73
POLCON V	34	0.75	0.10	0.44	0.89
POLCON III	34	0.47	0.11	0.26	0.86
Power Distance Index (PDI)	34	46.74	20.09	11	100
Individualism (IDV)	34	60.18	20.04	18	91
Masculinity (MAS)	34	49.68	24.83	5	100
Uncertainty Avoidance Index (UAI)	34	67.35	21.41	23	100
Long-Term Orientation (LTO)	34	51.65	21.43	21	100
Indulgence (IND)	33[a]	53.45	18.58	16	97
Control Variables		Mean	Std. Dev.	Min	Max
GDP per capita in $1000 (GDPPC)	34	29.57	16.69	6.49	76.27
Gross R&D expenditure as % of GDP (GERD)	34	1.75	0.93	0.35	3.86
Military spending as % of GDP (MILITARY)	34	1.78	1.24	0.15	7.30
Trade openness (exports + imports as % of GDP) (TRADE)	34	86.36	49.19	25.30	284.99
Fuel exports as % of merchandise exports (FUEL)	34	7.06	10.98	0.41	61.56
Education spending as % of GDP (EDUC)	34	5.09	1.16	2.86	8.09

[a]Data unavailable for Israel

It would be ideal to run a panel regression so as to understand the differences emanating from both cross-national and longitudinal variations in national innovative capacity. Since Hofstede's variables are only available as single-year cross-sectional data, however, we had to draw on a simple OLS regression without a time component. Yet we aggregated the data for all other variables that have yearly observations, using the mean values for the period of 1996 ~ 2012. Here is the regression model used for our analysis:

$$Y_i = b_0 + b_1(POLCON_i) + b_2(CULTURE_i) + X_i^{'}\beta + e$$

where the subscript i indexes a country, Y is the PCT patent applications per 100,000 residents, POLCON is the political constraint index (POLCON III or POLCON V), CULTURE is any one of Hofstede's cultural variables (PDI, IDV, etc.), and $X_i^{'}$ is a vector of control variables. Again, except for Hofstede's variables updated for 2010, all other variables are the average values of the 15 years from 1996 to 2012.

Results

Before showing the regression results we here provide a couple of the first-cut findings for the cultural correlates of innovative capabilities of OECD member states.

Presented in Table 2 is the correlation matrix for the major independent variables. Here our interest is in finding out if the cultural dimension of innovation as captured by Hofstede's variables is significantly related to the more formal aspect of decentralization measured by Henisz's political constraint index. Indeed, some of the cultural variables show significant correlations with the political constraint variable as well as with one another. Notable among them is the long-term orientation (LTO) that is positively correlated with the political constraint index. As expected, the power distance index (PDI) is negatively correlated with individualism and indulgence. Meanwhile, societies with greater

Table 2 Correlation matrix of cultural variables

	POLCON V	PDI	IDV	MAS	UAI	LTO
POLCON V	1.000					
PDI	-0.141	1.000				
IDV	0.214	-0.513***	1.000			
MAS	-0.100	0.224	0.118	1.000		
UAI	-0.053	0.564***	-0.639***	0.195	1.000	
LTO	0.393**	0.225	-0.104	0.255	0.236	1.000
IND	-0.279	-0.394**	0.241	-0.198	-0.462***	-0.548***

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

power distance turn out to be more averse to uncertainty as indicated their negative correlation coefficient. One should note that societies respecting individual freedom more as evidenced by higher IDV and IND values also tend to have lower degree of uncertainty avoidance. In particular, the degree of indulgence has a positive correlation with long-term orientation.

The next two figures visualize the relationship of the institutional and cultural attributes with the innovative capabilities of OECD member states. Figure 2 charts the political constraint variables (POLCON III and POLCON IV) against the patent data for each country. Figure 3 charts two of Hofstede's variables – PDI and LTO – with the same patent data.
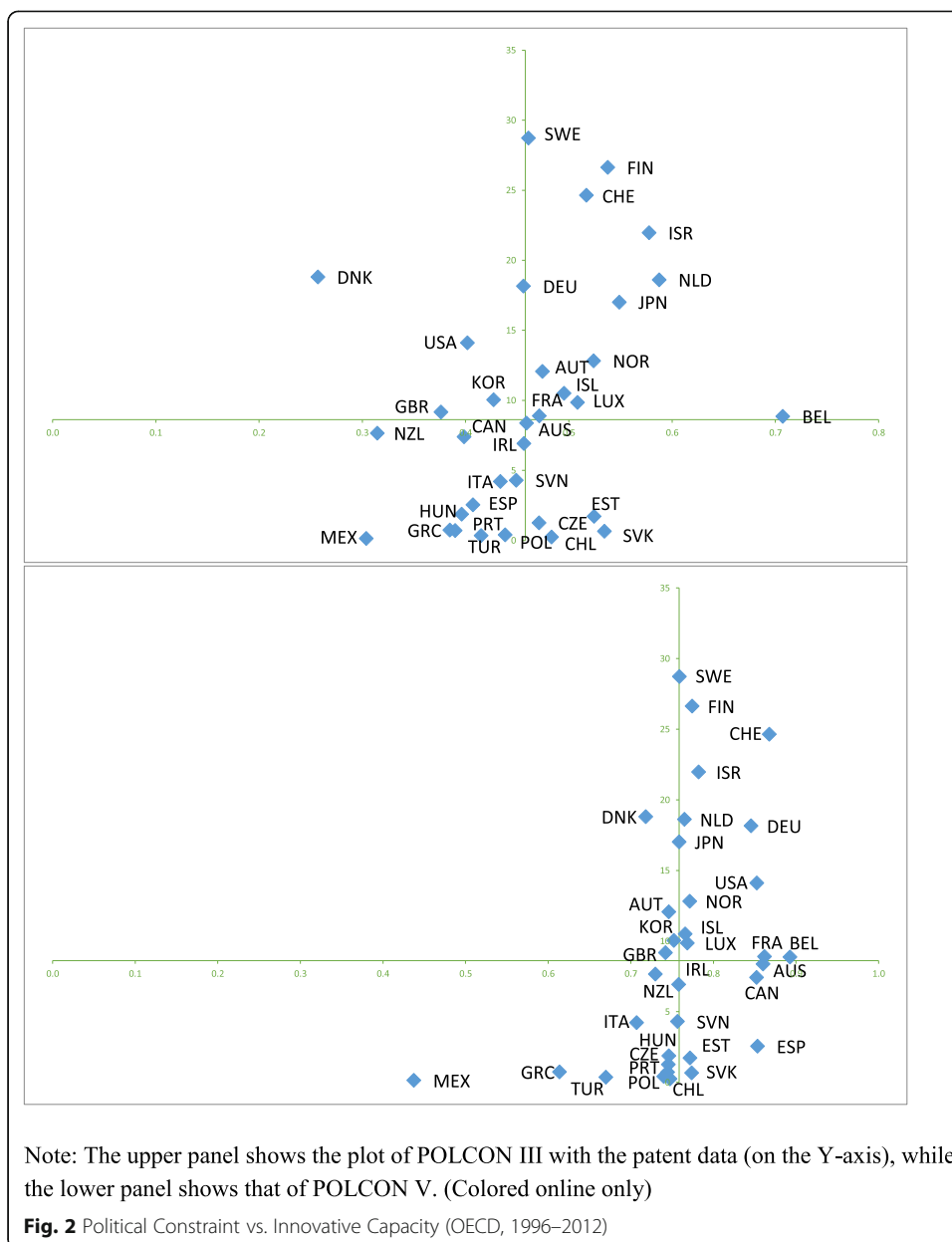
As revealed in Fig. 2, the OECD countries are scattered across four quadrants in both panels, which makes it hard to draw a trend line. In other words, there seems to be a weak linkage of political constraint with their innovative capabilities. Compared to the upper panel that plots POLCON III with the patents, the lower panel for the plot of POLCON V and the patents shows more densely distributed countries on the X-axis, as the OECD countries gather around in the range of 0.3 out of the 0 ~ 1 scale on POLCON V.[6]

In contrast, the cultural variables plotted in Fig. 3 show a relatively clear pattern of correlation with the patent data. As for the power distance index shown in the upper panel, the negative trend line suggests that the higher on the power distance index (PDI), the less innovative countries tend to be. The positive trend line of the lower panel indicates that countries with greater long-term orientation (LTO) tend to be more innovative.

The distribution of the OECD countries on the upper panel of the PDI plot seems to make common sense; more hierarchical societies of East Asia such as Japan and Korea lie in the first quadrant, respectively, whereas most West European countries lie in the second quadrant. Also, countries of Southern and Eastern European countries with more authority-based interpersonal relations lie in the fourth quadrant.[7] Notably, there is virtually no country falling in the third quadrant; in other words, no societies with more egalitarian interpersonal relations rank lower on innovative capacity as measured by patent applications.

The lower panel of the LTO plot indicates that long-term orientation is associated with moderately high levels of innovation, though the association is weaker than in the upper panel as revealed in a less steep trend line. Again, East Asian countries are located in the first quadrant together with several West European countries. These are the countries that are generally oriented to longer term goals at the same time showing

Jang *et al. Journal of Open Innovation: Technology, Market, and Complexity* (2016) 2:23

Page 9 of 16

Note: The upper panel shows the plot of POLCON III with the patent data (on the Y-axis), while the lower panel shows that of POLCON V. (Colored online only)

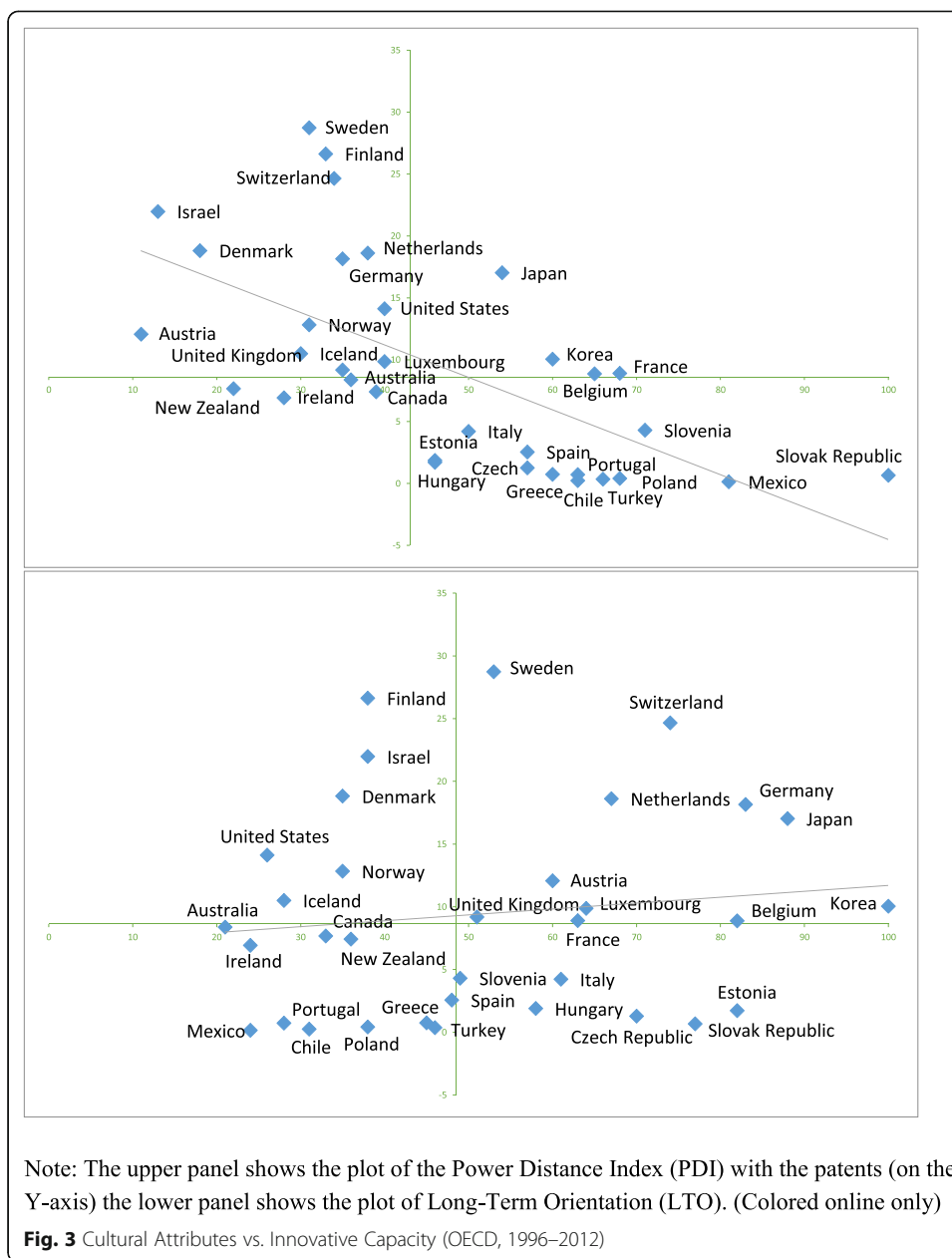**Fig. 2** Political Constraint vs. Innovative Capacity (OECD, 1996–2012)

higher-than-average patent application rates. In contrast, South and East European countries show lower-than-average patent application rates despite holding similar levels of long-term orientation.

From the two figures plotting the institutional decentralization as proxied by the political constraint index and cultural attributes as captured by Hofstede's measures, we could obtain some preliminary result that the latter variables seem to hold more explanatory power for national innovative capacity as the trend line is more visible in the second figure.

Now we present the findings from more systematic regression analyses of patent applications on those two key independent variables. In Table 3, the regressions were run on all independent variables, while two sets of regressions were run in Table 4 given a large degree of collinearity between GDP per capita and R&D spending.

Jang *et al. Journal of Open Innovation: Technology, Market, and Complexity* (2016) 2:23

Page 10 of 16

Note: The upper panel shows the plot of the Power Distance Index (PDI) with the patents (on the Y-axis) the lower panel shows the plot of Long-Term Orientation (LTO). (Colored online only)

Fig. 3 Cultural Attributes vs. Innovative Capacity (OECD, 1996–2012)

All six regressions with the full set of independent variables presented in Table 3 show quite a large adjusted R^2, which indicates that our independent variables explain roughly 90% of the variation observed in the patent applications of OECD countries. The upper rows displaying the regression coefficient estimates of the major regressors show a strong contrast between the political constraint index and the cultural variables. The former is insignificant in all regressions, while the latter is significant in three out of six regressions.

Those three cultural variables that turn out to be significant at the 90% level of significance are the power distance index, individualism, and long-term orientation. The PDI coefficient is significantly negative, implying that countries with more hierarchical power structure tend to generate fewer patent applications. In contrast, more

Jang *et al. Journal of Open Innovation: Technology, Market, and Complexity* (2016) 2:23

Page 11 of 16

Table 3 Full regression results

	Dependent variable: log of PCT patents					
Major IVs						
POLCON V	1.537	0.891	1.172	1.357	-0.036	0.443
PDI	-0.012*					
IDV		0.016***				
MAS			0.006			
UAI				-0.008		
LTO					0.012**	
IND						-0.005
Controls						
lnGDPPC	0.943***	0.843***	1.103***	1.040***	1.319	1.209***
GERD	0.787***	0.918***	0.820***	0.811***	0.605	0.815***
MILITARY	-0.046	-0.034	0.000	0.002	0.062	0.057
TRADE	0.002	0.002	0.002	0.002	0.001	0.002
FUEL	0.005	0.004	0.005	0.002	-0.002	0.000
EDUC	0.058	0.043	0.196*	0.070	0.259**	0.172*
Constant	-3.886***	-4.837***	-5.868***	-4.216***	-5.826***	-4.960***
Adjusted R^2	0.908***	0.932***	0.904***	0.905***	0.912***	0.896***
Obs.	34	34	34	34	34	33

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

individualistic culture is associated with greater innovative capacity, as indicated by the strongly significant positive coefficient on IDV. Long-term orientation is also positively linked to the dependent variable, indicating that patent applications are larger in more long-term oriented societies.

Among the control variables, GDP per capita and R&D expenditures have highly significant coefficients on all but the regression of long-term orientation where the education expenditure is the only significant control variable. In particular, one percentage point increase in gross domestic expenditure on R&D turns out to increase patent applications by as high as 0.9%.

As is well-known in the endogenous growth literature (Romer, 1994; Grossman & Helpman, 1993), R&D investment as technological input into the economy is a theoretically and empirically important factor of production. It is thus no surprise that R&D expenditure and GDP per capita are strongly correlated with each other. For the current sample, the pairwise correlation coefficient of these two variables is 0.51 (and 0.63 when GDP per capita is logged). We therefore ran separate regressions with each of these variables to see how the amelioration of the collinearity problem would affect the regression results.

The results of these separate regressions are shown in Table 4. The upper panel contains the regression results including the same controls but excluding the R&D expenditure, while the lower panel contains the results excluding the log of GDP per capita. In both regressions, adjusted R^2 got lower as expected. Interestingly, the cultural variables show different levels of significance between the two sets of regressions.

The regression excluding the log of GDP per capita show more significant coefficients than those excluding R&D expenditure, as GDP per capita would in general have

Table 4 Restricted regression results

	Dependent variable: log of PCT patents					
With lnGDPPC						
POLCON V	1.948	1.320	1.483	1.673	-0.822	0.613
PDI	-0.014					
IDV		0.010				
MAS			0.005			
UAI				-0.008		
LTO					0.023***	
IND						-0.011
Constant	-5.381***	-6.971***	-7.624***	-6.089***	-7.360***	-5.969***
Adjusted R^2	0.815***	0.815***	0.803***	0.806***	0.875***	0.803***
Obs.	34	34	34	34	34	33
With GERD						
POLCON V	2.816**	1.535	2.377	2.623*	2.489	2.725
PDI	-0.024***					
IDV		0.025***				
MAS			0.008			
UAI				-0.015**		
LTO					-0.002	
IND						0.010
Constant	-1.462***	-3.669***	-4.517***	-2.037***	-3.494***	-4.674***
Adjusted R^2	0.845***	0.880***	0.794***	0.815***	0.781***	0.787***
Obs.	34	34	34	34	34	33

Other controls included in the regressions are the same as the regressions of Table 3: Military spending, Trade openness, Fuel exports, and Education spending
***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$

more collinearity with other independent variables. It is of particular note that only long-term orientation (LTO) becomes insignificant in the regressions with R&D expenditure (i.e. excluding GDP per capita). This seems to be due to the possibility that the effect of long-term orientation is largely absorbed in R&D expenditure as R&D is essentially long-term investment. That is, the presence of R&D expenditure may well weakens the influence of long-term orientation.

Yet in the same regressions with R&D expenditure, three cultural variables turn out to be significant; the power distance index, individualism, and the uncertainty avoidance index. These three cultural variables all show the effects in the expected directions. Patent applications are likely to be larger in societies with less power hierarchy, societies with more individualistic values, and societies with less aversion to uncertainty. More specifically, the coefficient on PDI tells us that one standard deviation increase in the power distance index, i.e., 20 out of 100 – equivalent to the difference between Hungary (PDI = 46) and Turkey (PDI = 66) – would generate 0.48% fewer PCT patents per 100,000 people.

A similar size coefficient on IDV indicates that one standard deviation increase in individualism, equivalent to the difference between Spain (IDV = 51) and Sweden (IDV = 71), would lead to 0.5% more PCT patents per 100,000 people. Finally, one standard deviation difference in the uncertainty avoidance index (21 out of 100) would lead to 0.31% difference in the number of PCT patent applications per 100,000 people. Therefore Germany

showing the UAI of 65 would have 85,773 more patents than France showing the UAI of 86, given the negative effect of UAI on patent applications. The actual difference in the average patent applications between the two countries over the sample period is 925,985. Thus the estimated discrepancy of 85,773 in patent applications between the two countries ascribed to the difference in uncertainty avoidance accounts about 10% of the actual difference in patent applications.

Discussion

Our primary motivation for this study is to find out the cultural correlates of national innovative capacity given that the existing studies have largely looked into more formal, institutionalized features and conditions for technological innovation. Innovation prospers on free-thinking minds that are in turn more likely to bloom in societies allowing individual freedom. In this light, more decentralized countries that distribute great power among political and social entities and agents would be propitious for technological innovation. Yet the example of East Asian countries that achieved fast-track modernization with science and technology challenges such conventional explanation of institutional conditions underlying innovation.

Drawing on the well-known cross-national dataset on national culture, we have explored at length how various dimensions of national culture relate to the different rates of technological innovation as measured by patent applications. Our empirical analysis is designed to contrast the effects of political (and more institutionalized) feature of decentralization and those of cultural (and less formalized) factors. Controlling for a variety of factors typically included in the model of national innovative capacity such as R&D investment, openness to trade, and educational spending, we have shown that cultural variables – in particular, power distance, individualism, and long-term orientation – have significant impact on the national innovation rates. Societies with less hierarchical power structure, greater individual freedom and initiatives, and more value put on long-term goals turn out to generate a significantly larger number of patents.

Meanwhile, through the literature reviews on open innovation, we have also confirmed the importance of cultural adaption in order to fully leverage external know-how. Given such studies on cultural correlate with corporate innovation, one should find out a culture as an underlying factor penetrating societies from firm to national level. It is of particular significance to note that a favorable culture for innovation plays a pivotal role under various institutional apparatuses, both in NIS and for open innovation.

Only if the cultural assets guaranteeing relatively equal relationship and free discussions among people are built, will the institutional supports, from SMEs to governmental aid packages, such as intellectual property rights under law and R&D investment policies have a substantial effect.

This study makes contribution to the growing literature of cultural dimensions of national innovative capacity by adding a cross-national examination of the linkage of national culture and technological innovation to the field mostly dominated by the firm-level analyses. It is not without problems and limitations, however. First of all, although the number of countries included in the study is larger than in the previous study similar to ours (Taylor & Wilson 2012), it is still limited to fewer than forty countries the dataset itself is relatively small, making it hard to generalize beyond the countries included in the study. Secondly, given multicollinearity of most control variables, it was hard to

Jang *et al. Journal of Open Innovation: Technology, Market, and Complexity* (2016) 2:23

Page 14 of 16

single out clearly the effects of major independent variables – that is, political and cultural variables. One might consider a two-step process in which the residuals after the regressions of those control variables are examined further with the political and cultural variables.

Technological innovation is itself a highly complex phenomenon that is virtually impossible to be explained away with a handful of factors, especially at the national level, a more comprehensive model is called for to capture hitherto overlooked or underrated sources of national innovation capacity. Our study is just one such effort.

Endnotes

[1]While political decentralization is often taken to mean federalism in the US context, decentralization can be either vertical or horizontal. In horizontal decentralization, political power is shared among different branches of the government – typically executive, legislative, and judiciary branches. In vertical decentralization, political authority is distributed towards local governments away from the central government (Taylor 2007, p.233).

[2]As to the last mechanism, it is worth noting Tsebelis' work on veto players (Tsebelis 2002). He has shown that the number of veto players as well as their political distances have predictable political outcomes including policy stability.

[3]These dimensions are often abbreviated as PDI, IDV, MAS, UAI, LTO, and IND, respectively.

[4]Yet in some cases, collective culture also promoted innovation. To explore the effect of collectivism further, they classified it into two types – nationalism (patriotism) and familism (localism). It was the case of countries with collective culture featuring more nationalism or patriotism that showed a positive impact of collectivism on innovation.

[5]Openness to trade, military spending, educational spending are expected to have a positive effect on national innovation rates, while fuel exports are expected to have a negative effects largely due to the resource curse (Taylor & Wilson 2012). Military spending is also important control, especially in those countries that have a large amount of investment in military R&D. In fact, a bulk of the defense budget is carved out for the development of advanced weapons. While it would be more precise to use the amount of military R&D expenditure, we use the overall military expenditure like other studies mostly due to data availability.

[6]In particular, some countries (Denmark, the USA, and the Netherlands, for example) show a large shift towards political constraint from POLCON III to POLCON V. As mentioned earlier, POLCON III focuses on the balance between executive and legislative branches, while POLCON V includes the judiciary branch as well as local governments. The shift of these countries seems to be due to their polities being highly decentralized on the vertical dimension.

[7]This distribution of countries along the PDI dimension resonates with Samuel Huntington's nine civilizations (Huntington 1997). East Asian cultures have generally large power distance among societal members with strong emphasis on strict social order emanating from their Confucian tradition. People in West European countries tend to form more horizontal relations with narrower power distance than any other cultural spheres. For East European countries, the legacy of the Soviet Union seems to cast a long shadow.

Authors' contributions
YJ was mainly responsible for executing the study such as data collection and analysis. He reviewed the previous literatures, collected independent and dependent data, and conducted statistical analysis from the data. SYK contributed in two points. Firstly,she guided a direction of research into right way from the beginning and gave an important advice on making research plan. Secondly, she played an important role in making the draft as well. YK was mainly responsible for making the research plan and drawing conclusions from the data analysis. He offered counsel on formulation of the research purpose and direction. In particular, he advised on statistical limitations of this study and offered a hint for a future research. Both authors read and approved the final manuscript.

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Competing interests
I confirm that I have read SpringerOpen's guidance on competing interests and that none of the authors have any competing interests.

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