

IQ, cultural values, and the technological achievement of nations

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ABSTRACT

It is shown that the technological capabilities of a nation are related to national IQ. Nations with a higher percentage of high-IQ individuals generate more technological knowledge (as measured by patents granted per head of population) than other nations. Technological achievement is also shown to mediate the relationship between national IQ and per-capita GDP, suggesting that high-IQ nations are wealthier partly because they are more successful at generating technological knowledge. Additional variance in technological achievement, beyond that explained by IQ, is accounted for by cultural values; nations that value intellectual autonomy and social equality produce more technological knowledge. Intellectual autonomy was also found to moderate the relationship between technological achievement and national IQ, suggesting that technological progress is enhanced where high-IQ individuals live in an intellectually open environment.

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1. Introduction

The most significant transformation of society in recorded history has been the Industrial Revolution which began in eighteenth century Europe. According to Hart (2007) the 'modern era', which began around 1500 CE, has witnessed dramatic changes in the human condition, which are comparable in scale to those caused by the advent of agriculture, which marked the transition from the Paleolithic to the Neolithic era about 10,000 years ago (p. 325). The massive increase of global wealth over the past 300 years is rooted in the explosion of technological knowledge which powered this revolution, and which has continued ever since. Today, technological progress remains a major driving force of the global economy, and the ability of a nation to create and exploit new technological knowledge is a key ingredient of its economic success and the wealth and well-being of its citizens. Drucker (1993) declared "In fact, knowledge is the only meaningful resource today. The traditional 'factors of production' have not disappeared, but they have become secondary." (p.42).

Technological achievement has traditionally been studied from an economic perspective (e.g., Acs & Audretsch, 1989; Bound et al., 1984; Evenson, 1993; Hall, Griliches, & Hausman,

1986; Pakes & Griliches, 1984; Scherer, 1965, 1983; Schmookler, 1966). Typically the focus of such studies has been the firm or the industry sector, with spending on research and development, or numbers of scientists and technicians, as explanatory variables. This paper however considers technological achievement at the national level, and the explanatory variables are psychological rather than economic.

Three general propositions are advanced and examined: first, that technological achievement is a function of national IQ; secondly, that technological achievement mediates the relationship between national IQ and national wealth; and finally that technological achievement is related to national culture.

The rest of this paper is organized as follows. The use of patent counts as an indicator of national technological achievement is described first. The three propositions to be tested are then discussed and the research hypotheses formulated. The variables used are then described, and the analysis and results presented, and finally the implications of the findings are discussed.

1.1. Patents as an indicator of technological achievement

Economists have long been fascinated by patent statistics as an index of innovation and technological achievement

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(Griliches, 1990), and patenting in the US has been widely used as a basis for international comparisons (Archibugi & Pianta, 1992). Archibugi and Pianta (1996) noted several advantages of using patent counts as indicators of technological achievement: patents are public documents, statistics are available over long time periods, and there is a high degree of international comparability. Furthermore, since obtaining patent protection is time-consuming and costly, most patent applications will be for products and processes that are expected to deliver high benefits.

A patent is a document issued by a national government agency or a recognized regional authority (for example the European Patent Office) which grants the applicant(s) exclusive intellectual property rights for a specified time. According to the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement, World Trade Organization) patents may be granted for any inventions, whether products or processes, in all fields of technology, provided that they fulfil three criteria. First, the invention must be new (i.e. not previously known or used); second, it must involve an inventive or “non-obvious” step (i.e. a step not easily made by someone trained in the relevant area); and finally it must be useful (i.e. capable of industrial application). The invention must also be described in sufficient detail to enable one skilled in the field to use it for the stated purpose (sometimes called the “enablement” criterion).

The legal procedures for obtaining patent protection differ somewhat from country to country, but typically, an initial application is filed containing a full description of the invention, and claims defining the scope of protection requested; the patent office then conduct a search for any earlier published documents which affect the novelty or inventive step of the invention, and then the application is published (normally about 18 months after filing). The applicant then requests examination of the claims, and the patent office carries out a detailed examination, raising objections if appropriate and giving the applicant an opportunity to amend the application to overcome them. If all the objections are successfully surmounted, a patent is then granted, providing the applicant with protection for a specified period, usually about 20 years.

1.2. Technological achievement and national IQ

The analysis of IQ scores from a wide range of countries has revealed substantial differences amongst nations. (Lynn & Vanhanen, 2002, 2006). Estimates of mean national IQs range from 60–70, typical of many countries in sub-Saharan Africa, to 95–100 in Europe, and to 105 or more for some countries in the Far East. National IQ has been found to correlate with a variety of other national indicators such as per-capita GDP (Lynn & Vanhanen, 2006); average educational achievement (Lynn, Meisenberg, Mikk & Williams, 2007; Lynn & Mikk, 2007), economic growth (Weede & Kämpf, 2002); and educational enrolment, agricultural labour, and indicators of infant health (Barber, 2005). Importantly, Rindermann (2007a,b) has discovered a positive manifold encompassing national IQ scores and tests of academic achievement that suggests the existence of a g-factor (big G) of differences in national cognitive ability.

Devising an invention worthy of patenting clearly requires intelligence, and the level of patenting activity in a nation

should therefore be a function of national IQ. As Hart (2007) has remarked, it seems plausible to assume that most important inventions and innovations are made by persons with far greater than average intelligence (p. 23). The decisive influence on national patenting levels should thus be the number of high-IQ individuals in the population, rather than the mean national IQ. The simplest model is that the number of patents produced by a country is proportional to the number of high-IQ individuals in the population. To avoid statistical complications arising from large differences in country populations, it is convenient to work in proportions rather than raw numbers. This suggests the following hypothesis:

H1. The number of patent grants per million of population is proportional to the percentage of high-IQ individuals in the population.

1.3. Technological achievement as a mediator between national IQ and national wealth

It is proposed that technological achievement mediates the relationship between IQ and wealth; in other words, high-IQ nations generate more technical knowledge, which in turn leads to increased national wealth.

There is strong evidence for a positive association between national mean IQ and national wealth (Dickerson, 2006; Lynn & Vanhanen, 2002, 2006; Whetzel & McDaniel, 2006), and between IQ and economic growth rates (Weede & Kämpf, 2002). However, much remains to be understood about the mechanisms underlying these relationships. Shapiro, writing from an economic perspective, observed that: “... less than one-third of the growth rate of output per worker over the years from the turn of the [20th] century can be attributed to the rise in capital per worker. Over two-thirds of the growth rate of output per worker has therefore to be attributed to all other factors covered by the catchall called technological advance” (Shapiro, 1970, p. 493). Similarly, Rosenberg, Landau and Mowery (1992 p. 1) observed: “Research carried out over the last 30 years demonstrates that technological change is an important contributor to productivity growth and therefore to growth in the income and wealth of nations”. One plausible conclusion that might be drawn here is that high-IQ nations are wealthier than low-IQ nations because they are better able to innovate and generate technological knowledge. In other words:

H2. The relationship between national IQ and national wealth is mediated by levels of patenting activity.

1.4. Technological achievement and national culture

Although culture is a broad and variously conceived construct, a definition accepted by many anthropologists says that culture “... consists in patterned ways of thinking, feeling and reacting...” and its essential core is “... traditional (i.e. historically derived and selected) ideas and especially their attached values.” (Kluckhohn, 1951, p.86). A simpler definition, intended to embody the essence of Kluckhohn's description, has been suggested by Hofstede: culture is the “collective programming of the mind that distinguishes one group or category of people from another.” (Hofstede, 2001, p.9).

Most anthropologists and cross-cultural psychologists agree that values are a key element of culture. A value is “a conception ... distinctive of an individual or characteristic of a group, of the desirable” (Kluckhohn, 1951/1967, p. 395), or a “broad tendency to prefer certain states of affairs over others” (Hofstede, 2001, p. 5). Cultures can be distinguished from one another by the system of normative values they endorse. The most well-researched values systems of recent times are those of Hofstede (2001) and Schwartz (1994, 1999). Both authors have surveyed their respective value dimensions in a large number of countries. However, it is Schwartz's system that is preferred here for two reasons. First, Hofstede's sample of 50 nations (and three regions) excluded countries in the Soviet system, and respondents were employees of a single multinational company; Schwartz's sample of nations is both larger ($N=73$) and more representative at both the national and individual level. Secondly, the definitions of Schwartz's value dimensions allow more straightforward hypothesis generation.

Schwartz's (1994, 1999) system of human values is constructed around three dimensions that correspond to three fundamental principles of social organization, and the culture of a society is defined by its location on each of these dimensions.

Schwartz's first dimension concerns the relationship of the individual to the group. At one end of this dimension lie embedded (or conservative) cultures. In these cultures, the individual is viewed as embedded in, and identified with, the group, and finds meaning through his or her participation in the collective. Embedded cultures tend to emphasize maintenance of the existing social order, and encourage individuals to subdue personal inclinations that might disrupt the status quo. At the opposite end of this dimension lie autonomous cultures. In autonomous cultures the individual is regarded as a unique and self-sufficient being, who is encouraged to express and develop his or her special gifts, and is expected to challenge received wisdom where it hinders personal fulfilment. Schwartz recognized two aspects of autonomy. In cultures that emphasize *affective* autonomy, individuals are encouraged to pursue satisfying experiences; on the other hand, in cultures that emphasize *intellectual* autonomy individuals are encouraged to create and innovate, and to pursue their own ideas. This leads to the hypothesis:

H3.1. Cultures that value intellectual autonomy will have elevated levels of patenting activity.

Schwartz's second dimension concerns the means by which a society guarantees responsible behaviours that enable large numbers of people to live harmoniously together. In hierarchical cultures, individuals are assigned, and accept, social roles which are associated with specific obligations that limit their behaviours. In such cultures, an unequal distribution of power and authority is regarded as a socially necessary and desirable state of affairs. An alternative solution to the problem of maintaining social order is found in egalitarian cultures. Here, individuals are expected to recognize each other as moral equals, and to treat each other as they would wish to be treated themselves. Concern for others is regarded as a trait whose ethical value derives from its non-coercive nature. In hierarchical cultures, those higher in the hierarchy are expected to ‘know best’; we might therefore suppose that

change depends on the approval of those in authority, and that a new idea will be judged not purely on its merits, but on the social status of the originator. This would suggest that hierarchical cultures are resistant to new ideas. On the other hand, we might expect that in egalitarian cultures ideas are treated on merit and that the social status of the originator is not important. This leads to the following hypothesis:

H3.2. Hierarchical cultures will have reduced levels of patenting activity.

Schwartz's third cultural dimension addresses the proper relationship between Man and the rest of the world. Cultures that emphasize mastery believe that Man's role is to assert control, and to shape the world in accordance with his will to further the interests of the group in particular or humankind in general. This orientation is expressed as an endorsement of ambition, success, competitiveness, and daring. At the opposite end of this dimension, cultures that emphasize harmony believe that Man should adapt to the world rather than change it, an orientation which finds expression in appreciation of nature, and respect for the environment. The implication is:

H3.3. Cultures that emphasize mastery will have elevated levels of patenting activity.

2. Methods

2.1. Measures

2.1.1. National IQ and elite group size

Mean IQ scores for 113 nations were taken from Lynn and Vanhanen (2006). These scores, calculated relative to a mean of 100 and a standard deviation of 15 in Britain, are mostly, but not exclusively, based on non-verbal culturally-reduced tests (Raven's Progressive Matrices, Cattell Culture Fair, and the Goodenough Draw-a-Person test), and are corrected for increases in IQ with time (Flynn effect; Flynn, 1984, 1987).

The *elite group size* of a nation, denoted E_x , is defined here as the percentage of individuals in the population who have an IQ greater than some specified value X . For a homogeneous population, and assuming IQ is normally distributed as $N(\mu, \sigma)$, E_x is equal to $1 - \Phi(X)$ where Φ is the cumulative distribution function for the normal distribution with mean μ and standard deviation σ .

However, when the national population consists of distinct sub-populations with different mean IQs, E_x for the nation as a whole depends on the sizes and IQs of the sub-populations. A striking example is South Africa, which, as Lynn and Vanhanen (2001) have noted, is substantially wealthier than its mean IQ would predict. South Africa has a total population of 29.3 million and a mean IQ of 72. Assuming a standard deviation of 15 IQ points, only 85 individuals would be expected to have an IQ over 140. However, the population of South Africa consists of about 22 million Blacks (mean IQ 66), 4.1 million Whites (mean IQ 94), 2.6 million Coloureds (mean IQ 82), and 0.6 million Indians (mean IQ 83). The expected numbers of high-IQ individuals in each sub-population are respectively 9; 4440; 146 and 92 which equates to a total of 4637 for South Africa as a whole.

There were 13 countries for which the sizes and IQs of its sub-populations were available. For these countries, E_X was calculated from sub-population data, and for the remaining countries it was calculated from the mean IQ for the whole nation. In all cases, the standard deviation of IQ was assumed to be 15, and X was set at 140.

2.1.2. Per-capita GDP

Annual per-capita GDP in US\$ was obtained from the UN Statistics Division (n.d.), and averaged over the three years 2003–2005. No data were available for the Northern Mariana Islands.

2.1.3. Cultural values

National measures of Schwartz's cultural values were taken from the Schwartz Value Survey (Israel Social Sciences Data Centre, 2005). Schwartz's database currently contains values preferences for over 75,000 individuals from 73 countries, 63 of which overlapped with Lynn & Vanhanen's countries.

2.1.4. Patent indexes

Because of its industrial and economic might, patent rights granted in the United States are especially valued, and patenting in the United States can be considered an index of world-class technological innovation. Patenting activity in the United States was therefore considered separately from the rest of the world.

Domestic patents are patents processed by a national patent office that originate from within the same nation. Because of differences in local patenting laws and procedures, and because of the 'home advantage', counts of domestic patents are not strictly comparable across nations. This paper therefore focuses on foreign patents. A foreign patent is defined here as either (i) a patent granted by a national patent office where the patent originated from a different nation; or (ii) a patent granted by a supra-national patent authority such as the European Patent Office.

To control for differences in country size, the national level of patenting activity was represented by the count of patents granted per million of the population (the patent index). Annual patent counts for the 113 Lynn and Vanhanen nations were retrieved from the Internet. Counts of patents granted outside the United States (up to 2005) were retrieved from the web site of the World Intellectual Property Organization (n.d.). The missing data rate was substantially higher for years prior to 2003, so the present analysis was restricted to the years 2003 to

2005. Counts of utility patents (patents for inventions), granted annually in the United States for 2003–2005 were retrieved from the Web site of the US Patent and Trademark Office (USPTO Patent Technology Monitoring Team, 2006).

For grants made within the US jurisdiction and outside it, patent counts were almost perfectly correlated across years, and the counts used in this paper were therefore represented by their respective three-year averages. Plotting counts in the US jurisdiction against counts in the non-US jurisdiction revealed one strong outlier, the US itself, which had a far higher than expected count of grants in the US than would be expected from its non-US grants. This is presumably because US applicants either have advantages in filing in their own country which non-US applicants do not have (i.e., a domestic advantage), or because they have a greater propensity than non-US applicants to file at home rather than abroad. In any case, to ensure compatibility across nations, patents granted to US applicants in the US jurisdiction were eliminated from the dataset.

This procedure delivered US patent counts for 102 nations, and non-US patent counts for 90 nations. Missing values were estimated from counts of patent filings (patents applied for) in the relevant jurisdiction. First, where national data was absent from both the US and non-US filings in the period (Central African Republic, Congo, Equatorial Guinea, Laos, Nepal, Tonga, Yemen), the patent grant counts were assumed to be zero. The missing values that remained were then estimated from filings in the period 2003–2005. The number of filings was multiplied by the relevant proportion of grants to filings (.375 for filings in the US and .453 for non-US filings) to give the estimated number of grants.

Finally, the three-year average count of grants was divided by the national population (in millions) to give the patent indexes for each nation in the US and non-US jurisdictions respectively. Population data was taken from the CIA World Factbook (Central Intelligence Agency, 2004).

3. Analysis and results

3.1. Univariate and bivariate statistics

Examination of the distributions of the study variables indicated that the patent indexes, per-capita GDP and elite group size were positively skewed, and natural logarithm transformations were applied to improve normality. Because

Table 1
Univariate statistics and correlations

	N	Mean	Standard deviation	1	2	3	4	5	6	7	8	9	10	11
1 National IQ	113	86.71	11.81	–										
2 Elite group size (%)	113	0.15	0.27	.68***	–									
3 Elite group size (log)	113	–4.14	3.13	.98***	.60***	–								
4 Patent index, US	112	20.85	48.47	.51***	.64***	.47***	–							
5 Patent index, US (log)	112	–1.51	4.19	.75***	.61***	.75***	.64***	–						
6 Patent index, non-US	112	65.03	147.47	.42***	.43***	.41***	.83***	.57***	–					
7 Patent index, non-US (log)	112	0.39	3.65	.67***	.54***	.67***	.62***	.76***	.65***	–				
8 Per-capita GDP	112	11,435.19	14,911.27	.56***	.47***	.54***	.61***	.70***	.73***	.75***	–			
9 Per-capita GDP (log)	112	8.28	1.65	.71***	.50***	.71***	.53***	.79***	.57***	.85***	.84***	–		
10 Intellectual autonomy	63	4.31	0.35	.63***	.31*	.63***	.39**	.65***	.54***	.69***	.71***	.73***	–	
11 Hierarchy	63	2.38	0.46	–.21	.10	–.21	–.13	–.38**	–.29*	–.43***	–.53***	–.48***	–.59***	–
12 Mastery	63	3.96	0.20	–.01	.14	.01	–.12	–.05	–.23	–.09	–.16	–.12	–.13	.49***

* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$.

Table 2

Correlations for nations with elite group sizes calculated from sub-population data

	Patent index US (log)	Patent index non-US (log)	Per-capita GDP (log)
N	12	13	13
National mean IQ	.61*	.48	.65*
National mean IQ (log)	.59*	.47	.64*
Elite group size (log)	.83***	.64*	.78**

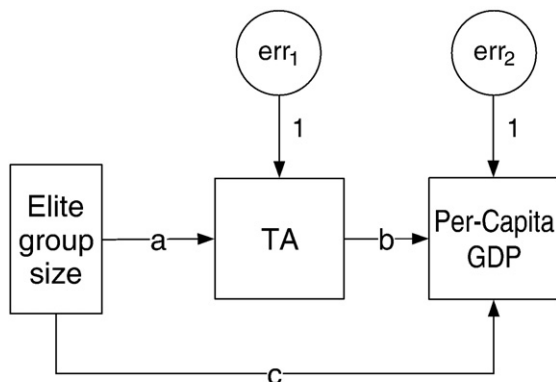
* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$.

some patent indexes were zero and the logarithm of zero is undefined, to avoid loss of data a small “starting value” (.001) was added to all patent indices before logging. As recommended by Tukey (1977, p. 397) this starting value was considerably smaller than the smallest non-zero value of the untransformed variable (.005 for US grants and .006 for non-US grants).

Univariate statistics and bivariate correlations for the untransformed study variables, and for the transformed variables used in subsequent analyses are shown in Table 1.

The results in Table 1 conform to expectations and prior research. First, there is a strong correlation between IQ and raw elite group size, and an almost perfect correlation between IQ and log elite group size. The correlation between IQ and wealth is by now well established, and exactly what was expected. The correlations of elite group size with the two indexes of patenting activity (.64 and .43 for the untransformed variables, and .75 and .67 for the transformed variables) provide initial support for hypothesis H1. Furthermore, as predicted by hypotheses H3.1 and H3.2, autonomous cultures have higher levels of patenting activity, and hierarchical cultures have lower levels. However, H3.3, which predicted elevated levels of patenting in mastery cultures is not supported.

The results overall do not suggest that elite group size is a better predictor of technological achievement than the national average IQ. However, elite group size is preferred to mean IQ in subsequent analyses for two reasons. First, there can be little doubt that patenting is a process involving high-IQ individuals, and a model based on elite groups seems more realistic than one based on average IQs. Secondly, when the analysis is restricted to countries where elite group sizes were calculated

Note: TA = technological achievement; err_1 , err_2 = error variances.**Fig. 1.** Path model for estimating the mediating role of technological achievement.**Table 3**

Mediating effects of technological achievement on the IQ–wealth relationship

	Jurisdiction	
	US	Non-US
Standardized path coefficients		
Elite group size → knowledge generation (a)	.75**	.67**
Knowledge generation → per-capita GDP (b)	.59**	.69**
Elite group size → per-capita GDP (c)	.26*	.25**
Mediation effect	.44**	.46**
% mediation	62.7	65.1
% variance explained	65.0	76.0

* $p \leq .002$, ** $p \leq .001$.

from sub-population data, a clear difference emerges as shown in Table 2.

Patenting activity and GDP correlate noticeably more strongly with elite group size than they do with either raw or logarithmic mean IQ. Although this stronger association is not clearly evident in the correlations reported for the larger dataset, elite group size was used as the predictor in subsequent analyses.

3.2. Technological achievement as a mediator of the IQ–wealth relationship

The mediating effect of technological achievement was estimated using path analysis. The general form of the path model is shown in Fig. 1, where the observed variables are represented by rectangles.

The circles labelled err_1 and err_2 are (unobserved) error variances, which represent variance in the endogenous variables not explained by the predictors. The rectangle labelled TA represents an indicator of technological achievement (in this case, a patent index).

The arrows represent model paths, and the labels indicate their strength. In this model, the direct effect of elite group size on performance is represented by path c, and the indirect (mediation) effect by paths a and b. The strength of the

Table 4

Hierarchical regression of technological achievement on IQ and cultural values

	US jurisdiction		Non-US jurisdiction	
	Step 1	Step 2	Step 1	Step 2
Model 1 (autonomy)				
Standardized coefficients				
Elite group size (E)	.67***	.93***	.55***	.88***
Intellectual autonomy (I)	.23*	.13	.33***	.20*
$E \times I$.28***		.36***
R^2	.69	.73	.65	.71
ΔR^2		.04**		.06***
Model 2 (hierarchy)				
Standardized coefficients				
Elite group size (E)	.77***	.77***	.71***	.72***
Hierarchy (H)	-.22**	-.21**	-.27***	-.26**
$E \times H$		-.04		-.10
R^2	.70	.70	.65	.66
ΔR^2		.00		.01

Note: $N = 62$ for both models. R^2 for final models are underlined.* $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$.

mediation effect is $a \times b$, and the percentage mediation (i.e. mediation effect / total effect) is given by $\frac{axb}{(axb+c)}$. In the analyses described below, all the variables were entered in logarithmic form, and model parameters were derived using the default maximum likelihood estimation procedure of the modelling program Mplus 5.0 (Muthén & Muthén, 1998–2007). This estimation method can handle missing data, so each model was estimated using all 113 nations. To ensure the model was identified (solvable), the path coefficients from the error variance components were fixed at 1 as shown in Fig. 1.

Two different path models were estimated (one for each patent jurisdiction) and the results are shown in Table 3. The path coefficients are reported in standardized form, and can thus be interpreted as standardized regression coefficients.

The first three data rows of Table 3 show the standardized path coefficients for the paths depicted in Fig. 1. The next row shows the mediation or indirect effect, with the significance level for the null hypothesis of no mediation. This is followed by the percentage mediation, and the percentage of variance in per-capita GDP accounted for by the independent variables in the model.

The results indicate a sizeable mediating effect. Some 62% to 65% of the effect of elite group size on wealth can be explained by technological achievement. Together, elite group size and patenting activity explain a considerable proportion of the variance in per-capita GDP.

3.3. The effect of cultural values on patenting activity

Both elite group size and the cultural values of intellectual autonomy and hierarchy correlate with patenting activity. To

see if IQ and cultural values explain unique variance in national technological achievement, the patent indexes were regressed on elite group size and culture simultaneously. Because cultural values were available for only a subset of nations, these analyses were restricted to a smaller dataset.

Two regression models were examined. In Model 1 the predictors were elite group size, intellectual autonomy, and their interaction, and in Model 2 the predictors were elite group size, hierarchy, and their interaction. To avoid problems of multi-collinearity, the predictor variables were centred about a mean of zero prior to computing the interaction term (see e.g., Aiken & West, 1991). In each case, the first-order variables were entered simultaneously in Step 1, and the interaction term in Step 2. Interaction terms were retained in the final model only if they increased the variance explained by a significant amount. The results are shown in Table 4.

The results in both jurisdictions are similar. First, the significant regression coefficients for elite group size and cultural values show that IQ and culture explain unique amounts of variance in patenting activity; after accounting for elite group size, intellectual autonomy has a positive effect on patenting, and hierarchy has a negative effect, providing further support for hypotheses H3.1 and H3.2.

In Model 1, the changes in R^2 at Step 2 are significant, indicating that intellectual autonomy moderates the relationship between elite group size and patenting in both jurisdictions; however, in Model 2, the changes in R^2 are small and non-significant, indicating no moderating effects of hierarchy. Overall, the predictors explain a substantial amount of the variance in national patenting activity. Based on the respective final models, the predictors explain 71% to 73% of this variance in Model 1, and 65% to 70% in Model 2.

To aid interpretation of the moderating effects of culture, the Model 1 results were graphed following the procedure recommended by Aiken and West (1991, Ch. 2). In each jurisdiction, the predicted values of the patent index were plotted for high and low autonomy cultures, and for large and small elite groups (where high/large was defined as 1 SD above the mean, and low/small was defined as 1 SD below the mean). The results are shown in Fig. 2.

The graphs indicate that when the elite group size is small, intellectual autonomy has little effect on patenting; however, for nations with large elite groups, patenting activity in high autonomy nations is considerably higher than in low autonomy nations.

4. Discussion

This research was subject to some limitations that should be kept in mind when interpreting the results. As is common in many cross-cultural studies, the unit of analysis was the nation state. Some nations are highly diverse and composed of distinct sub-populations, each of which may have a different mean IQ. Apart from 13 countries for which heterogeneous sub-population data was available, such intra-national variations in IQ are excluded from consideration in the present study. Secondly, patent counts have some limitations as indicators of technological achievement, because some patents reflect important advances in technology, and others merely reflect incremental improvements. Patent documents contain citations to previous patents, and it

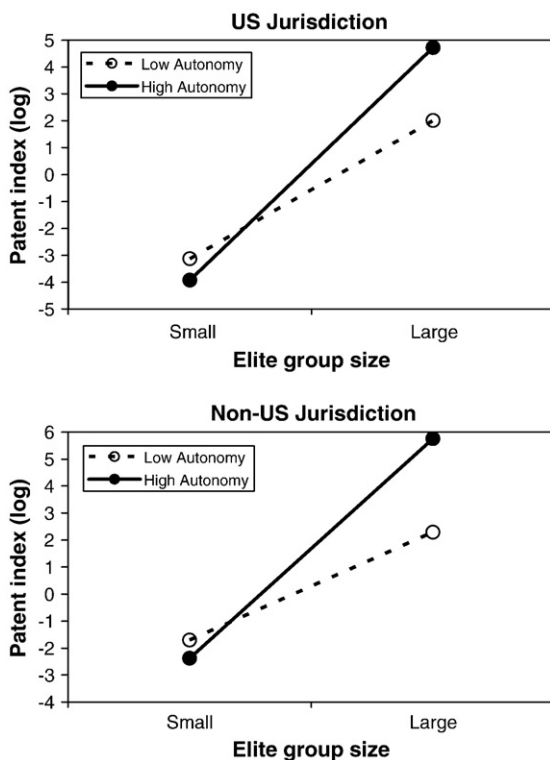


Fig. 2. Interaction of autonomy and elite group size.

has been suggested that the economic or technical importance of a patent can be measured by the number of times it is cited. (OECD, 1994). However, for large aggregations of patents, patent counts and patent citations show similar patterns (Grupp & Schmoch, 1992), so this is unlikely to be a major threat to the validity of the present findings.

Another limitation is that elite group sizes were not observed directly, but were calculated from national mean IQs on the basis of three assumptions. The first assumption was that the lower bound for elite IQ is 140. To investigate whether a different cut-off would produce different conclusions, all calculations were repeated with elite group sizes based on a cut-off of 120 instead of 140. The correlation between the two measures of elite group size was .96; the mediating effect of patenting on the IQ–wealth relationship was virtually unchanged, (increasing from 65.1% to 65.4% for US patenting, and from 62.7% to 63.8% for non-US patenting); and none of the regression coefficients in Table 4 changed by more than .02, all significance levels being preserved. This demonstrates that the conclusions of this research are robust to substantial differences in the definition of the elite group. The second assumption is that the standard deviation of IQ is the same ($SD=15$) in all populations. Raising or lowering the SD, but maintaining the same value across populations should have similar effects to changing the cut-off size. Elite group sizes for the national populations and for the sub-populations of the 13 heterogeneous nations were re-calculated with SDs of 12 and 18, and correlated with the original sizes calculated with an SD of 15. The correlations were: $r=.96$ (for $SD=12$) and $.98$ (for $SD=18$). It is however possible that the SD varies systematically with the group mean IQ. For example, it has been estimated that the SDs for US Blacks and US Whites are respectively 13 and 15. To examine this effect, elite group sizes were calculated with an SD proportional to the mean national IQ ($SD=15+(\text{mean IQ}-100)/12$) producing SDs in the range 11.8 to 15.7 for the sample nations. Elite group sizes calculated on this basis correlated .99 with sizes based on a fixed SD of 15. The third assumption underlying the estimation of elite group size is that all population and sub-population IQs are normally distributed. This is unlikely to be strictly true; however, it is safe to conclude that given the basic assumption of normality, the results presented here are robust to a range of SD and lower-bound assumptions.

As in any empirical study, the correlations between the observed variables underestimate the correlations between the underlying constructs because the observed measures are not perfectly reliable indicators of their constructs. Evidence for the reliability of national mean IQs has been presented by Lynn and Vanhanen (2006). For 71 nations for which two independent measures of IQ have been obtained the correlation between these was .95. For the GDP and patent measures, correlations were examined between the years 2003, 2004 and 2005. For per-capita GDP, the correlations were .998, .996 and .990 for the periods 2003–2004, 2004–2005, and 2003–2005 respectively. These are not significantly different from each other, indicating that the relative standing of nations is the same across years (Schmidt & Hunter, 1996). Cronbach alpha for the average three-year GDP measure was .996. For the US patent counts, the corresponding year-on-year correlations were .987, .996, and .990, and for the worldwide patent counts they were .896, .980 and .929, in neither case differing significantly across years. The

Cronbach alpha reliabilities for the three-item patent measures were .99 for the US counts and .97 for the non-US counts. The reliability of the national cultural means was estimated by splitting the data into two random samples, and correlating the mean scores of the two samples. For intellectual autonomy, hierarchy and masculinity, the correlations were .97, .97 and .95 respectively, indicating a high level of reliability for the national means. Given the high reliability of the measures, the expected corrections for reliability in this study will be quite small.

The strong association between elite group size and technological achievement found here is consistent with previous research showing that national IQ is highly correlated with measures of academic achievement. This lends further credence to the conception of national IQ as a measure of national differences in cognitive ability.

The results also shed light on the well-established relationship between national mean IQ and national wealth. The strong mediating effect of technological achievement suggests that much of the wealth of high-IQ nations is a consequence of their greater technological prowess. This has policy implications. Lynn and Vanhanen (2001) suggested that disparities in national wealth could be reduced by introducing better nutrition, education and health care in low-IQ countries so as to raise the mean IQ. However, the heterogeneous nations in the sample provided an opportunity to test (albeit with a small sample size) whether national IQ or elite group size was the better predictor of technological achievement and per-capita GDP. The finding that elite group size was a markedly stronger predictor suggests that an alternative strategy would be to identify, educate, and nurture high-IQ individuals within the indigenous population, or even encourage the immigration of high-IQ groups. Further data on the IQs of sub-populations in a larger sample of heterogeneous nations would be of great interest in this context.

It is also clear that national culture is a predictor of technological achievement, adding incrementally to the variance in patenting activity explained by national IQ. First, nations whose social structure is hierarchical generate less technical knowledge than egalitarian nations. Hofstede (2001, p101) cites supporting evidence: between 1901 and 1960 high power distance (i.e. hierarchical) countries produced fewer Nobel Prizes in science per capita than low power distance countries. Secondly, nations that value independence of thought (intellectual autonomy) have elevated levels of technological achievement. However the effect of intellectual autonomy on achievement depends on national IQ. In low-IQ nations, differences in autonomy have a negligible effect on patenting, implying that establishing a culture that encourages intellectual independence is likely to lead to higher achievement only in high-IQ nations. Intellectual autonomy seems to function as an enabling factor, which cannot compensate for a low national IQ, but which can raise levels of technological achievement in high-IQ nations.

In theory it might be possible to improve the technological capabilities of a nation by increasing egalitarianism and encouraging independent thinking. But given national cultures are deeply-rooted and stable phenomena, with historical roots going back over centuries (Hofstede, 2001, p.11) would this be realistic in practice?

There is considerable disagreement over the mechanisms by which cultural values are transmitted, and in particular over the relationship between culture and genetics. Laland, Odling-

Smee, and Feldman (2000) discuss various evolutionary models. The sociobiological perspective proposes that culture is an extension of the phenotype, and like other aspects of the phenotype it is an expression of naturally-selected genes. It has been demonstrated that national populations have reliably different personality profiles (e.g., Allik & McCrae, 2004; Schmitt, Allik, McCrae & Benet-Martinez, 2007), which has led to the suggestion that national cultural values are a reflection of genetically determined personality traits. For example, McCrae (in Hofstede & McCrae, 2004) has argued that the hierarchical nature of present-day Latin societies is not merely a legacy from the Roman empire, but stems from a genetically based personality syndrome of high neuroticism and disagreeableness which necessitates a cultural emphasis on law and order. This kind of model, although it does not involve a gene for hierarchy, would if strictly applied preclude change in fundamental cultural values. Gene–culture co-evolutionary theory on the other hand supposes that shared cognitive phenomena like beliefs and values are learned and socially transmitted as a cultural inheritance. In an extended version of this model, Laland et al. propose that populations can and do modify their ecological environment, a process they call 'niche construction', which bestows an ecological inheritance on successive generations in addition to their genetic and cultural inheritances. New selective pressures arising from the niche ecologies can then modify the gene pool. In these more flexible models, cultural values interact with the genome, and are amenable to change.

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