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This study examines two key issues about the role of cognitive human capital (also known as intelligence) for economic growth between 1975 and 2009: (1) the measures of cognitive human capital that are most relevant to the prediction of economic growth; and (2) the proximate mechanisms through which this form of human capital promotes economic growth. We find that cognitive ability, measured as IQ or school achievement, robustly predicts economic growth on a worldwide scale. These two measures can be averaged into a single measure of "intelligence." In multivariate analyses that include a measure of cognitive ability, length of schooling is a poor predictor of economic growth. The growth-promoting effect of cognitive ability is mediated by multiple mechanisms, including lower fertility and greater technological competitiveness in developing countries, and increased domestic saving rate and reduced burden of infectious diseases in all countries. The main conclusion is that rising intelligence has been a major determinant of economic growth in the recent past.

Key Words: Human capital; Economic growth; School achievement; Intelligence.

Few economists doubt that the wealth of nations depends to a large extent on human capital, defined as the skills, attitudes and personality traits that people translate into economic activities. Less agreement exists about the best way of measuring human capital. Traditionally, human capital has been measured by the quantity or quality of education (e.g., Lutz, 2009). Measures of human capital that have been used in growth regressions include average years of schooling, school life expectancy, and enrollment in primary,

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secondary and/or tertiary education (Barro and Lee, 1993, 2001; Levine and Renelt, 1992; Sala-i-Martin et al, 2004).

Studies predicting economic growth with these "traditional" indicators have produced mixed results. Although negative results have been blamed on suboptimal data quality (Cohen and Soto, 2007; De la Fuente and Doménech, 2006), there is a more important theoretical limitation to this approach. The problem is that years in school and educational degrees measure inputs into education, but not the cognitive and non-cognitive skills that children acquire (or fail to acquire) in school. Although we can expect a correlation between educational inputs and outputs, this correlation is not necessarily strong.

More relevant than mere exposure to schooling are the skills that children acquire in school. Non-cognitive effects of schooling are difficult to measure, but we do have fairly accurate measures of cognitive skills. Two such measures are available at the country level. The first consists of the results of international scholastic assessments in mathematics, science, reading and other curricular subjects. The two most useful testing programs are the Trends in International Mathematics and Science Study (TIMSS) and the Program of International Student Assessment (PISA). Several other assessments have been done, providing us with a data set of scholastic achievement for 148 countries.

Earlier work has compared the effects of average years of schooling and average scores on scholastic assessments. In most studies, scholastic test results were found to be more important than length of schooling for the prediction of economic growth (Hanushek and Kim, 1995; Hanushek and Kimko, 2000; Hanushek and Woessmann, 2007, 2009). However, the importance of test scores for economic outcomes is not undisputed. Ramirez et al (2006) reported that the effect of student achievement on economic growth between 1970 and 1990 was due mainly to the inclusion of the four "Asian Tigers". However, the quantity and possibly the quality of country-level cognitive test data has improved greatly during the last few years, and this earlier result needs to be evaluated with updated data sources.

An independent data set has been compiled by Richard Lynn and Tatu Vanhanen (2001, 2002, 2006). It consists of data for the average IQ in the country, scaled to a mean of 100 and standard deviation of 15 for Britain ("Greenwich IQ"). The original studies had been performed by many independent investigators who used different methods and theoretical frameworks, and the results are of uneven quality. Nevertheless, the correlations of "national IQ" with the results of international studies of scholastic achievement are in the vicinity of 0.9 (Lynn and Mikk, 2007, 2009; Lynn et al, 2007; Lynn and Meisenberg, 2010; Meisenberg and Lynn, 2011).

Both Lynn & Vanhanen (2002, 2006) and others (Hunt and Wittmann, 2008; Whetzel & McDaniel, 2006) noted a strong relationship between IQ and per-capita GDP. Dickerson (2006) found that a difference of 10 points in national IQ corresponds to a roughly two-fold difference in per-capita GDP. More importantly, relationships of national IQ with economic growth have subsequently been reported (Jones and Schneider, 2006; Weede, 2004; Weede and Kämpf 2002).

The first aim of the present study is to bridge the hitherto separate research traditions using either scholastic assessments or IQ by determining whether these two measures are equivalent as predictors of economic growth between 1975 and 2009. A second aim is an investigation into the mechanisms by which these cognitive measures are translated into economic growth. Earlier studies have presented evidence for a positive effect of intelligence on savings rates (Jones and Podemska, 2010), as well as on scientific achievement and economic freedom (Rindermann and Thompson, 2011). We systematically evaluate these and several other hypothesized mechanisms as possible mediators of the intelligence effect on economic growth. We postulated that several measures are potential mediators of the intelligence effect: (1) general macrosocial conditions, including freedom/democracy, economic freedom, corruption, income inequality, and size of government; (2) economic variables, including the trade volume and the proportion of GDP allocated to investment, government and consumption; (3) technological competitiveness; (4) population health, operationalized with measures of life expectancy and infectious disease burden; (5) the welfare state, measured as social security expenses; (6) fertility rate; and (7) economically important behavioral measures including savings rate and prevalence of crime. The results are discussed in the historical context of macroeconomic trends in the 20th and early 21st centuries.

Methods

Several country-level measures were used:

School achievement is available for 148 countries and territories. For 92 countries, the score was computed from assessments of 8th-graders in the TIMSS studies of 1995, 1999, 2003 and 2007 and 15-year-olds in the PISA studies of 2000, 2003, 2006 and 2009. Scores for 39 additional countries were available from other scholastic testing programs. These were extrapolated into the TIMSS-PISA data set as described in Lynn & Meisenberg (2010) and Meisenberg & Lynn (2011). For 17 additional countries (including 9 with information about economic growth), scores were calculated from the results of the International Mathematics Olympiads conducted between 1981 and 2010, based on data in Rindermann (2011). After residualization for population size and communist history, results of the Mathematics Olympiads correlate with the remaining school achievement data at $r = .662$ ($N = 86$ countries) and with IQ at $r = .696$ ($N = 81$ countries).

IQ is defined by the "national IQs" reported in Lynn & Vanhanen (2006), with the amendments and extensions reported in Lynn (2010). Minor corrections were used for Morocco (Sellami et al, 2010) and Saudi Arabia (Batterjee, 2011) based on more recent results. This data set includes 137 countries and territories.

Intelligence is the average of IQ and school achievement for those countries that have both measures, with weighting for data quality as described in Lynn & Meisenberg (2010) and Meisenberg & Lynn (2011). IQ or school achievement alone was used for countries having only one of these measures. 136 countries with a population size of more than 250,000 (excluding small countries, whose economic development is more likely to be atypical) had information about both economic growth and cognitive test data. For 95 of these, the intelligence score was averaged from IQ and school achievement. For 25 countries it is based on school achievement only, and for 16 countries on IQ only.

Education measures length of schooling for adults 25+ years old, based on the Barro-Lee data set for 143 countries (http://www.barrolee.com/data/dataexp.htm). Missing data points were extrapolated from World Bank and United Nations sources.

GDP is per capita GDP adjusted for purchasing power from the Penn World Tables 4.0 (Heston et al, 2011), with missing data extrapolated from the World Development Indicators of the World Bank. GDP was log-transformed because a fixed increment in cognitive ability is expected to raise per-capita GDP by a constant fraction, not a constant amount.

No corruption was averaged from Transparency International's Corruption Perception Index for the years 1998-2003 (http://www.transparency.org) and the *no corruption* measure of the World Bank's Governance Indicators 1996 or earliest available date. High values indicate low corruption.

Economic freedom is the average from the unrotated first factors of maximum-likelihood factor analyses of areas 2-5 of the Fraser Institute's economic freedom index for the periods 1975-2005 (Gwartney et al, 2010), and domains 1, 2, and 5-8 of the Heritage Foundation index for 1995-2005 (http://www.heritage.org/index/Download.aspx). Unlike the published economic freedom indices from these two sources, this index has acceptable construct validity.

Big government is averaged from domain 1 of the Fraser Institute's Economic Freedom index (1975-2005 average) and the *Fiscal Policy* and *Government Expenditure* sections of the Heritage Foundation index (1995-2005 average). Although published as part of the *Economic freedom* indices of these organizations, these domains are factorially unrelated to the other components of these indices and have different correlates, as shown in Table 1. Whereas *Economic freedom* as defined in this study measures the amount of red tape and legal restrictions for businesses, *Big government* measures, in large part, the redistributive activities of government.

Freedom/Democracy is averaged from two source variables: (1) political freedom defined as the averaged scores of political rights + civil liberties from Freedom House at http://www.freedomhouse.org/research/freeworld, average 1975-2005; and (2) democracy, defined as Vanhanen's democracy index (average 1975-2004), from the Finnish Social Science Data Archive at http://www.fsd.uta.fi/english/data/catalogue/FSD1289/. The correlation between these two measures is $r = .847$, N = 179 countries. Missing data were extrapolated from the Voice and Accountability measure of the World Bank's Governance Indicators, 1996 or earliest available date (http://info.worldbank.org/governance/wgi/pdf/wgidataset.xls).

Social security is averaged from % of budget expended on social security in 2001 (United Nations, 2004) and social security as % of government expenditures (Kurian, 2001).

Gini index is derived mainly from the World Income Inequality Database (WIID2a) of the United Nations University, as described in Meisenberg (2007).

Savings rate is gross domestic savings, 1975-2005 average, from the World Bank at http://data.worldbank.org/indicator/NY.GDS.TOTL.ZS?page=4.

Investment %GDP, *Government %GDP* and *Consumption %GDP* are % of GDP spent for investment, government and consumption, respectively, from the Penn World Tables 4.0 (Heston et al, 2011). The correlation of *Government %GDP* with *Big government* is only .177 (N = 162 countries).

Openness is trade volume as proportion of GDP, from the Penn World Tables 4.0 (Heston et al, 2011).

Technology is a measure computed from 8 topics of the Global Competitiveness Report (GCR) 2001/02 (World Economic Forum, 2002), with missing data extrapolated from the 2010/11 GCR (http://www.weforum.org/issues/global-competitiveness): unique products, sophisticated production processes, sophisticated marketing, quality of research institutions, buyer sophistication, log-transformed patents/capita, company innovation, and company R&D spending. GCR topics that are unrelated to *technological* competitiveness (e.g., bribe taking, freedom to fire employees) were not used. Missing data were extrapolated from the average of log-transformed royalties/capita, patents/capita, scientific articles/capita, and books published/capita, obtained from the World Development Indicators of the World Bank and the Human Development Reports of the United Nations. The average of these four indicators correlated at r = .859 with the GCR-derived measure.

Oil exports/capita is from the CIA at https://www.cia.gov/library/publications/the-world-factbook/, retrieved July 2010.

Life expectancy is life expectancy at birth, average of 1970-75 and 2000-05, from the Human Development Report 2005 of the United Nations (http://hdr.undp.org/en/reports/).

Infections is a measure of disability-adjusted life years lost due to infectious and parasitic diseases in 2002 (WHO, 2004).

TFR is the total fertility rate, 1975-2005 average, from the World Bank's World Development Indicators (http://data.worldbank.org/indicator).

Crime is a measure of crime victimization derived from the Gallup World Poll (http://www.gallup.com/poll/world.aspx). It is calculated as the unrotated first principal component of the proportion reporting theft during the last year, proportion reporting assault/mugging, and proportion feeling unsafe on the streets at night.

Population density is the log-transformed population density in 1997 from the World Development Indicators of the World Bank., with missing data extrapolated from the World Fact Book of the CIA.

World regions were defined similar to Inglehart et al (2004). *Protestant Europe* was defined as the traditionally Protestant countries of northern and central Europe, except Britain. *English-speaking countries* include the British Isles and English-speaking overseas nations with mainly European-origin population. *Catholic Europe (& Mediterranean)* contains the Catholic countries of southern Europe and also Greece, Cyprus and Israel. *Middle East* refers to the predominantly Muslim countries from Morocco to Pakistan. *Africa* includes only countries of sub-Saharan Africa. *South (+ Southeast) Asia* is a heterogeneous group of countries ranging from India to the Philippines. *East Asia* includes countries with predominantly Confucian culture: China, Japan, Hong Kong, South Korea, Taiwan and Singapore.

All statistical evaluations were done with SPSS 16. Amos 16 was used for path models.

Results

Correlations

Table 1 shows correlations between economic growth, human capital measures, and other development indicators. Because the ex-communist countries of Eastern Europe have followed different economic trajectories from the rest of the world, the correlations are shown separately for all 93 countries that have complete data, and for the 86 countries without communist history.

Several results stand out. First, IQ and school achievement are highly correlated (.886 for the complete sample), confirming earlier results with less complete data (Lynn and Mikk, 2007, 2009; Lynn and Meisenberg, 2010; Meisenberg and Lynn, 2011). The correlation is higher than the correlations among other development indicators, supporting the validity of both IQ and school achievement as indicators of cognitive human capital at the country level. Another important observation is that the cognitive measures are related to lgGDP, but the similarly high correlations of lgGDP with the other development indicators show that it would be difficult to prove any causal relationship between static measures of GDP and cognitive abilities. Although cognitive ability is a plausible cause of economic wealth, it is equally plausible that wealth raises cognitive ability, either directly or through the educational system.

Temporal change in economic wealth is more tractable. Reverse causation is less likely when *change* in per-capita GDP is related to hypothesized predictors that are measured for the period over which the change is observed. Table 1 shows that economic growth is related significantly to IQ and school achievement, but not to most of the other indicators. The only other variables that correlate at least

Table 1. Correlations of human capital measures with economic and political variables. Correlations below the diagonal are for all countries with complete data (N = 93). Correlations above the diagonal are for countries without communist history only (N = 86). Correlations higher than .205 (all countries) or .213 (non-communist countries) are significant at p<.05.

	Gr	**IQ**	**SA**	**Sch**	**lgGDP**	**noCor**	**Fr/De**	**EcoFr**	**BG**
1. Growth 1975-2009	1	.401	.424	.187	.077	.207	.139	.298	-.139
2. IQ	.417	1	.889	.779	.744	.727	.727	.748	.053
3. School achievement	.453	.886	1	.747	.724	.735	.684	.766	.147
4. Schooling	.101	.745	.718	1	.740	.768	.749	.774	.217
5. lgGDP 1975-2009	-.024	.678	.660	.725	1	.695	.557	.711	.130
6. no corruption	.097	.671	.670	.730	.691	1	.724	.849	.376
7. Freedom/Democr.	-.024	.630	.565	.691	.560	.714	1	.641	.310
8. Econ. Freedom	.116	.636	.612	.665	.672	.819	.667	1	.105
9. Big government	-.072	.085	.195	.257	.121	.333	.216	-.003	1

marginally with economic growth are economic freedom and freedom from corruption in the non-communist sample.

Prediction of economic growth

Table 2 shows regression models in which economic growth is predicted with cognitive measures along with schooling and other predictors. Models 1 and 2 compare school achievement and IQ. Both measures are highly effective. The only other effect that is both powerful and consistent is log-transformed GDP in 1975, which has a negative relation with economic growth. The positive effect of low initial prosperity on subsequent economic growth is a well-known phenomenon that is sometimes described as the advantage of backwardness (Weede, 2004; Weede and Kämpf, 2002). The results show that the countries with the best growth prospects are those in which cognitive ability is higher than expected from present per-capita GDP – a good rule of thumb for investors. Model 3, which increases the sample size by using the composite measure of intelligence, shows essentially the same results.

Predictors other than lgGDP and the cognitive measures have weaker and less consistent effects. Schooling, freedom from corruption, economic freedom, oil exports and high population density tend to favor economic growth, while Big government, freedom/democracy and the abandonment of communism seem to be unfavorable. The small magnitude of the schooling effect is noteworthy because it suggests that schooling affects economic growth mainly through the cognitive skills that children acquire in school, rather than through non-cognitive skills such as conscientiousness, discipline and conformity.

When individual world regions were added to model 3 individually, only East Asia was related significantly to economic growth. Model 4 shows the result, with non-predictors removed from the model. The effect of intelligence is only mildly attenuated, contrary to the finding of Ramirez et al (2006) that inclusion of the Asian Tigers eliminated most of the cognitive ability effect. This argues against spatial autocorrelation (Dobson & Gelade, 2012; Eff, 2004) as the main reason for the effects of the cognitive measures.

Table 2. Prediction of economic growth between 1975 and 2009 with schooling, IQ, school achievement and other variables. Standardized β coefficient and t value are shown.

	Model 1		Model 2		Model 3		Model 4	
	β	t	β	t	β	t	β	t
School achievement	.764	7.08						
IQ			.869	8.09				
Intelligence					.828	8.12	.720	6.65
Schooling	.228	1.72	.196	1.42	.212	1.66	.171	1.41
lgGDP 1975	-.897	7.10	-.834	6.54	-.881	7.39	-.840	7.10
No corruption	.087	0.58	.073	0.50	.095	0.72		
Economic freedom	.147	1.07	.144	1.04	.155	1.23	.140	1.55
Big government	-.163	1.96	-.010	0.13	-.112	1.52	-.111	1.70
Freedom/Democracy	-.139	1.21	-.332	2.81	-.199	1.77		
Ex-communist	-.135	1.79	-.129	1.78	-.140	2.05	-.104	1.60
Oil exports/pop.	.224	2.50	.158	1.75	.201	2.43	.226	2.98
lg Popul. density	.115	1.64	.146	2.11	.116	1.81		
East Asia							.212	3.03
N	115		109		131		131	
Adjusted R^2	.516		.540		.525		.542	

Model 1 in Table 3 shows further evidence against spatial autocorrelation. When all world regions are included as predictors in addition to intelligence, with Protestant Europe as the omitted control, the intelligence effect is greatly attenuated but is still significant. Massive attenuation of the intelligence effect is expected because 78% of the variance in country-level intelligence is between rather than within world regions. The remaining intelligence effect suggests that even the modest intelligence differences between countries in the same world region are sufficient to affect economic growth.

When additional variables (described in the Methods section) were introduced individually into Model 3 of Table 2, several proved to be significant or marginally significant ($p<.1$) predictors. Model 2 in Table 3 shows the result when all these variables are included simultaneously. Elimination of non-predictors resulted in the more streamlined Model 3, which has reduced collinearity. Importantly, inclusion of the additional variables attenuates the intelligence effect without eliminating it. This suggests that some but not all of the intelligence effect is mediated by measurable factors such as investment rate, savings rate, and total fertility rate (TFR).

Tables 2 and 3 include all countries for which data are available. However, the determinants of economic growth can be different at different levels of economic development. Therefore logGDP in 1975 and 2009 were averaged, and a median split was applied. Table 4 shows some results for the subsamples of “rich” and “poor” countries. Models 1 and 3 show that intelligence strongly predicts economic growth in both kinds of country. Models 2 and 4 were developed from models 1 and 3 by adding a set of variables that had been significant predictors when added to the original model individually. This was followed by elimination of non-predictors and re-introduction of variables that had not been used before or had been eliminated during development of the model. We see that the introduction of other variables attenuates the intelligence effect without eliminating it, suggesting again that some of these variables may mediate effects of intelligence on economic growth. With the exception of the savings

Table 3. Prediction of economic growth between 1975 and 2009 with the composite measure of intelligence.

	Model 1		Model 2		Model 3	
	β	t	β	t	β	t
Intelligence	.454	2.52	.482	3.70	.517	4.53
Schooling			.073	0.49		
lgGDP 1975			-1.052	7.80	-.979	9.25
No corruption			.236	1.67	.182	1.77
Economic freedom			.068	0.52		
Big government			.017	0.23		
Freedom/Democracy			-.208	1.50	-.139	1.14
Ex-communist	.047	0.49	-.197	2.46	-.204	2.96
Oil exports/pop.			.069	0.98	.091	1.31
lg Popul. density			.076	1.17		
Catholic Europe	.144	1.44				
English-speaking	.012	0.13				
Latin America	.182	1.17				
Middle East	.118	0.81				

	Model 1		Model 2		Model 3	
	β	t	β	t	β	t
South Asia	.408	3.36				
East Asia	.478	5.14				
Africa	.312	1.29				
Pacific islands	.061	0.78				
Social Security			-.247	2.03	-.247	2.28
Investment %GDP			.141	1.91	.169	2.68
Consumption %GDP			-.042	0.40		
Life expectancy			-.138	0.57		
TFR			-.661	3.80	-.680	4.96
Savings rate			.234	2.08	.258	3.63
Infections			-.183	1.37		
N	136		114		117	
Adjusted R^2	.416		.640		.665	

Table 4. Prediction of economic growth between 1975 and 2009, separately for "poor" and "rich" countries. Standardized β coefficient and t value are shown.

	Poor countries				Rich countries			
	Model 1		Model 2		Model 3		Model 4	
	β	t	β	t	β	t	β	t
Intelligence	.763	6.97	.306	2.56	.520	5.21	.407	4.68
Schooling	-.003	0.02	-.140	1.22	.156	1.42	.224	2.72
lgGDP 1975	-.367	3.11	-.340	3.63	-.908	8.75	-1.037	12.06
No corruption	.161	1.50			.209	1.41	.196	1.75
Economic freedom	.103	0.80			.050	0.35	-.298	2.65
Big government	.121	1.11			-.150	1.73	-.178	2.51
Freedom/Democracy	-.067	0.59	-.135	1.58	-.137	1.16	.341	3.11
Ex-communist	-.154	1.57			-.205	2.51	-.290	4.55
Oil exports/pop.	-.022	0.22			.477	4.47	.436	4.74
lg Popul. Density	.143	1.49			.237	3.27	.134	2.03
Savings rate			.154	1.74			.256	3.21
Social security			-.311	3.26				
Government %GDP			.137	1.73				

	Poor countries				Rich countries			
	Model 1		Model 2		Model 3		Model 4	
	β	t	β	t	β	t	β	t
Investment %GDP			.227	2.63				
Openness							.247	3.28
Technology			.185	1.78				
Crime rate							-.359	4.86
TFR			-.571	3.74				
N	65		59		65		59	
Adjusted R^2	.533		.700		.716		.842	

rate, which promotes economic growth in both rich and poor countries, these effects are different for the two types of country.

Path models

Growth regressions can only suggest that part of the intelligence effect might be mediated by another measurable variable, but provide no strong evidence of causal paths. Therefore path models were employed in which causal relationships were specified explicitly. Figure 1 shows a simple model in which log-transformed per-capita GDP in 2009 is predicted with log-transformed per-capita GDP in 1975 and (abandoned) communism as the only exogenous variables. Other variables, including intelligence, are endogenous. The model fit is good, and the causal relations are theoretically meaningful: high lgGDP in 1975 and communist history increase the amount of schooling, schooling and lgGDP in 1975 raise intelligence, and in addition to lgGDP in 1975, high intelligence and freedom from corruption raise lgGDP in 2009. Communist history increases corruption. Approximately 8% of the intelligence effect on lgGDP 2009 in Figure 1 is indirect, being mediated by reduced corruption.

The saturated path model of Figure 2 was constructed to investigate plausible variables as mediators of the intelligence effect. Variables were considered mediators of the intelligence effect if they (1) are affected substantially by intelligence independent of the other variables in the model, *and* (2) have a significant effect on lgGDP 2009 independent of the other variables. These models were constructed separately for all countries, poor countries only, and rich countries only.

Table 5 shows the results. Paths in which both the IQ → M effect and the M → lgGDP effect have a statistical significance level of $p<.100$ are shown in bold. Mediator variables that produced significant paths in at least 2 of the 3 samples include the Gini index, social security spending, infectious disease burden, and total fertility rate (TFR). However, in each case the mediator accounted for only a small to moderate fraction of the intelligence effect. The direct path from intelligence to lgGDP in 2009 remained strong and statistically significant at $p<.001$ in each case, with the exception of the infectious

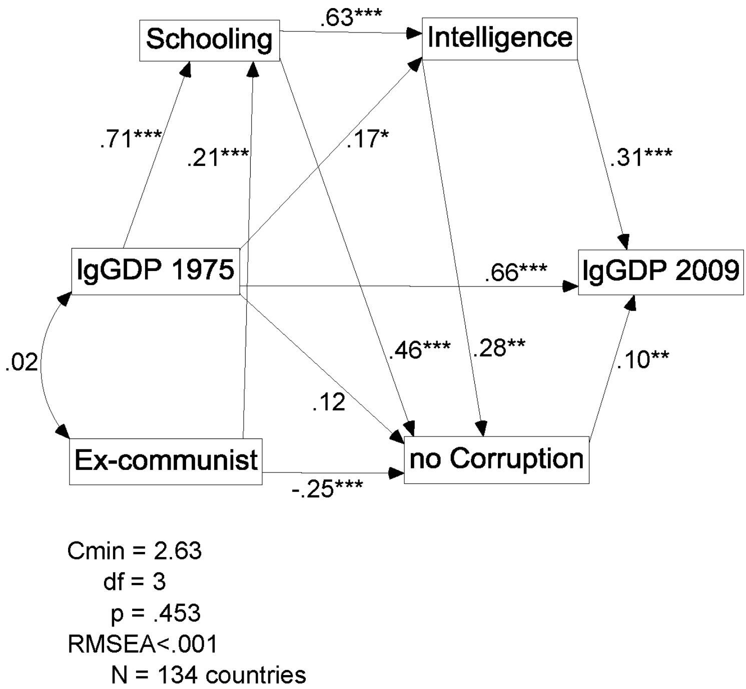

Figure 1.
Path model predicting log-transformed per-capita GDP in 2009. Error terms of the endogenous variables (each with a regression weight fixed at 1) are omitted. *, p<.05; **, p<.01; ***, p<.001.

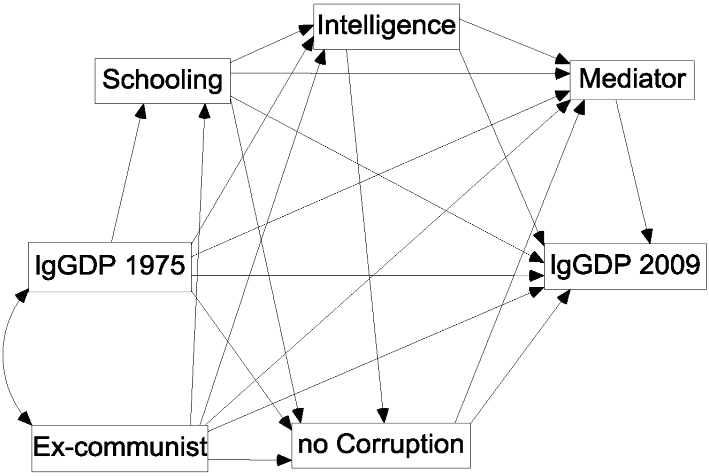

Figure 2.
Saturated model in which the effect of intelligence on log-transformed GDP in 2009 can be through a mediator variable. Results are summarized in Table 5.

Table 5. Paths from intelligence (IQ) to lgGDP 09 in the path model of Figure 2. Shown are the path coefficients (β) and significance levels (p) for the paths from intelligence to the mediator variable (M) and from the mediator variable to lgGDP2009. Direct refers to the Intelligence → lgGDP09 path in Figure 2. % indirect is the percentage of the IQ effect (not including the path through corruption) accounted for by the mediator variable.

	IQ → M		M → lgGDP09		Direct		
	β	p	β	p	β	% indirect	N
All countries							
Freedom/Democracy	.027	.750	-.025	.531	.303	-0.2	133
Economic freedom	.008	.927	.013	.754	.302	0.0	133
Big government	-.142	.301	-.055	.028	.295	2.6	129
Gini index	-.489	<.001	-.031	.346	.287	5.0	114
Social security	**.218**	**.016**	**-.080**	**.053**	**.320**	**-5.8**	**118**
Investment %GDP	**.257**	**.055**	**.064**	**.009**	**.286**	**5.4**	**134**
Government %GDP	-.026	.850	-.019	.428	.302	0.2	134
Consumption %GDP	**-.197**	**.083**	**-.065**	**.023**	**.289**	**4.2**	**134**
Openness	.057	.675	.057	.019	.299	1.1	134
Savings rate	**.353**	**.001**	**.110**	**<.001**	**.264**	**12.8**	**131**
Life expectancy	**.428**	**<.001**	**.155**	**.009**	**.236**	**21.9**	**130**
Infectious diseases	**-.681**	**<.001**	**-.127**	**<.001**	**.216**	**28.6**	**128**
TFR	**-.434**	**<.001**	**-.169**	**.001**	**.229**	**24.3**	**134**
Technology	.163	.014	-.012	.804	.304	-0.6	134
Crime	-.389	<.001	-.031	.274	.290	4.0	134

	IQ → M		M → lgGDP09		Direct		
	β	p	β	p	β	% indirect	N
Poor countries							
Freedom/Democracy	-.099	.456	.072	.247	.448	-1.6	67
Economic freedom	-.219	.083	.067	.308	.455	-3.3	67
Big government	-.093	.537	-.080	.151	.433	1.7	66
Gini index	**-.539**	**<.001**	**-.178**	**.005**	**.344**	**21.8**	**63**
Social security	.123	.266	-.037	.660	.445	-1.0	60
Investment %GDP	.201	.090	.064	.363	.428	2.9	67
Government %GDP	.120	.403	-.026	.650	.444	-0.7	67
Consumption %GDP	-.262	.057	.020	.747	.446	-1.2	67
Openness	-.009	.946	-.113	.067	.440	0.2	67
Savings rate	.357	.007	.064	.325	.418	5.2	65
Life expectancy	.489	<.001	.139	.151	.373	15.4	66
Infectious diseases	**-.630**	**<.001**	**-.165**	**.035**	**.337**	**23.6**	**67**
TFR	**-.480**	**<.001**	**-.268**	**.002**	**.312**	**29.2**	**67**
Technology	**.238**	**.046**	**.238**	**<.001**	**.384**	**12.9**	**67**
Crime	-.418	.002	.003	.964	.442	-0.3	67

	IQ → M		M → lgGDP09		Direct		
	β	p	β	p	β	% indirect	N
Rich countries							
Freedom/Democracy	.076	.493	-.132	.124	.353	-2.9	66
Economic freedom	.211	.047	.054	.551	.332	3.3	66
Big government	-.083	.601	-.085	.173	.336	2.1	63
Gini index	**-.246**	**.018**	**-.302**	**.005**	**.269**	**21.6**	**51**
Social security	**.313**	**.018**	**-.151**	**.058**	**.390**	**-13.8**	**58**
Investment %GDP	.278	.089	.060	.301	.327	4.9	67
Government %GDP	-.191	.238	.006	.924	.344	-0.3	67
Consumption %GDP	-.038	.775	-.288	<.001	.332	3.2	67
Openness	.027	.873	.204	<.001	.338	1.6	67
Savings rate	.207	.142	.263	<.001	.289	15.9	66
Life expectancy	.450	<.001	.046	.639	.322	6.0	64
Infectious diseases	-.689	<.001	-.094	.191	.279	18.8	61
TFR	-.398	<.001	.000	.997	.343	0.0	67
Technology	.196	.035	-.100	.325	.363	-5.7	67
Crime	**-.278**	**.052**	**-.149**	**.020**	**.302**	**12.1**	**67**

disease model for rich countries, where the statistical significance of the intelligence → lgGDP 2009 path was only .002.

Discussion

Relationship between schooling, IQ and school achievement

This study produced several important results. First, the results of IQ tests compiled by Lynn and Vanhanen (2001, 2002, 2006, 2012) are closely related to achievement in international scholastic assessments such as TIMSS and PISA, confirming the results of earlier studies using less complete data (Lynn and Mikk, 2007, 2009; Lynn and Meisenberg, 2010; Meisenberg and Lynn, 2011). In addition to being highly correlated, these two measures have virtually the same non-cognitive correlates and predict economic growth to similar extents. Therefore use of a composite measure of "intelligence" (or cognitive ability, or cognitive human capital) from IQ and scholastic assessments is recommended for future studies. Such a measure is expected to be more accurate than either measure alone for countries having both, and it maximizes the number of countries with cognitive test data by including those having information about either school achievement or IQ but not both.

Schooling has only small (but positive) effects on economic growth independent of the cognitive measures, suggesting that cognitive rather than non-cognitive effects of schooling are most important for economic growth. Exposure to formal schooling is still an important measure of human capital for studies of economic growth even when cognitive test data are available, because it may play a role in the rational application of intelligence in daily life and because it can foster attitudes and behaviors that either favor or inhibit economic growth. For example, we observe that in both developing countries and advanced economies, schooling is approximately as effective as intelligence in reducing the total fertility rate when both variables are used as co-predictors.

Robustness of the intelligence effect

The coefficients of Model 4 in Table 2 and Model 1 in Table 3 show that the growth-promoting effect of high intelligence is unlikely to be an artifact of spatial autocorrelation, which can produce false positive results in comparative studies (Dobson & Gelade, 2012; Eff, 2004). Intelligence remains a predictor even when world regions are controlled. Conversely, when economic growth in the 10 world regions is predicted with intelligence and log-transformed GDP in 1975, the familiar result is obtained: Intelligence raises, and pre-existing wealth reduces economic growth ($p = .001$ for both, data not shown). The conclusion is that intelligence is related to economic growth both in comparisons between broadly defined world regions and in comparisons between countries within world regions.

This contrasts with an earlier study, which found that the effect of mathematics and science achievement on economic growth between 1970 and 2000 was due mainly to the inclusion of the "Asian Tigers" (Ramirez et al, 2006). The discrepancy is likely due to the use of a far larger data set in the present study, and to the different time periods over which growth was measured.

Another important observation is that the effect of intelligence can be demonstrated both in developing countries and in advanced economies. Inspection of the coefficients in Table 4 shows that the effect is somewhat stronger in poor than in rich countries. This observation refutes the once popular belief that cognitive tests are "biased" against non-western nations and cannot produce valid predictions in such populations (Greenfield, 1997; van de Vijver and Poortinga, 1997).

Mediators of the intelligence effect

Little is known about the mechanisms by which high (or rising) intelligence has promoted economic growth in the recent past. Gelade (2008) and DiPietro (2004) attributed the higher per capita GDP of countries with higher average IQ to the greater technological achievements or creativity of high-IQ nations. Intelligence is also associated with a preference for delayed rather than immediate rewards. This mechanism has been proposed to account for some of the positive economic effects of high intelligence at the country level (Jones and Podemska, 2010).

With this study, we provide the first systematic search for mediators of the intelligence effect on economic growth, including a variety of institutional, economic, behavioral and biological variables. Because the expected relationships are complex and might be prone to methodological artifacts, we used two different methods: growth regressions, and path analysis. The following is a brief assessment of the observed results for the tested variables:

1. *Democracy and political freedom*. A positive effect of intelligence on democracy has been postulated by Rindermann (2008), based on cross-lagged models with scholastic achievement data. Democracy, in turn, has been examined extensively for effects on economic growth, with mixed results (Doucouliagos and Ulubaşoğlu, 2008; Tavares and Wacziarg, 2001). However, earlier studies of democracy effects on economic growth did not include the important variable of cognitive ability. In our models, the freedom/democracy variable has inconsistent effects in growth regressions and path models containing a cognitive measure (Tables 2-5). More surprising is that intelligence is not an important determinant of freedom and democracy in the path models of Table 5. Freedom/democracy is related most closely to schooling and freedom from corruption (data not shown). The causal arrow between democracy and corruption is debatable. When in the complete sample the corruption → freedom/democracy arrow of the path model is reversed, the marginal (non-significant) negative effect of democracy on lgGDP 2009 is offset almost exactly by the indirect path from freedom/democracy to corruption and corruption to lgGDP 2009. In this case education is the major positive effect on freedom/democracy, with a small positive effect from intelligence.

2. *Economic freedom and Big government*. These measures were abstracted from the "economic freedom" indices of Fraser Institute and Heritage Foundation. Overall, their effects on economic growth are surprisingly weak and somewhat inconsistent, although economic freedom is more likely to favor and Big government is more likely to retard economic development (except in Model 4 of Table 4). Because intelligence has only small and inconsistent effects on these variables, they are not important mediators of the intelligence effect. Economic freedom is related most closely to freedom from corruption, and Big government is favored by communist history and

freedom from corruption. Although not entirely ineffective, these measures seem to be less important for economic growth than is often believed.

3. *Gini index*. High average intelligence is known to be associated with low income inequality as measured by the Gini index, especially for countries with low to average intelligence (Meisenberg, 2007, 2008a). These earlier results are fully confirmed in the present study. We also observe negative effects of income inequality on economic growth, especially when poor countries and rich countries are analyzed separately. This confirms earlier reports of a negative effect of income inequality on economic growth (Panizza, 1999). It does not support the frequently held view that high income inequality favors economic growth by providing incentives for achievement, and we find no evidence that "...higher inequality tends to … encourage growth in richer places." (Barro, 2000, page 5).

   The direct negative effect of high income inequality on economic growth may nevertheless be spurious. It is possible that a shortage of highly skilled individuals in a country leads to high income inequality because it reduces competition for high-level jobs and increases the skill premium. This same shortage of highly skilled individuals is likely to retard economic development. Thus high income inequality may be an indicator for a shortage of specifically those skills that are important in the labor market, above and beyond the general cognitive skills that are measured by IQ tests and scholastic assessments.

4. *Social security spending* is favored by high intelligence but also tends to retard economic growth. Through this mechanism, high intelligence can *reduce* economic growth. This does not necessarily mean that high intelligence engenders enthusiasm for high social security spending. Another possibility is that high IQ reduces fertility and thereby raises the old age dependency ratio. Social security expenses rise and economic growth slows because of a rising proportion of pensioners in the population.

5. *Financial resource allocation.* Resource allocation to investment, as opposed to government and private consumption, is expected to

favor economic growth. We do indeed find mildly positive effects of the investment share and mildly negative effects of the consumption share on economic growth. Intelligence, in turn, tends to favor investment over consumption, although these effects do not always reach statistical significance. These relationships are seen best in the path models of Table 5.

6. *International trade ("Openness")* is usually considered favorable for economic growth, although empiric evidence does not always support this view (Kneller et al, 2008). In our models, openness favors economic growth for rich countries but not poor countries (Tables 4 and 5). It is not an important mediator of intelligence effects on economic growth because the path models of Table 5 show no substantial effects of intelligence on this variable.

7. *Savings rate.* This variable is interesting because a low rate of delay discounting is the personality trait that is most closely related to savings (as well as investment), and low delay discounting is known to be associated with higher intelligence at the individual level (Shamosh and Gray, 2008). Gross domestic savings, interpreted as indicator of time preference, have been proposed as mediator of intelligence effects by Jones and Podemska (2010). Our results replicate the results of these authors, suggesting that perhaps 10% of the intelligence effect on economic growth is mediated by this path.

8. *Technological competitiveness.* Gelade (2008) and DiPietro (2004) proposed that technological achievement and creativity mediate positive effects of intelligence on the economy. These hypotheses receive only partial support. Although the path models in Table 5 show significant effects of intelligence on technological competitiveness, the strongest determinant of technological competitiveness as defined here is not intelligence but freedom from corruption. Another result is that technological competitiveness promotes economic growth in poor countries but not rich countries. This is unexpected because the validity of technological competitiveness indicators has been questioned specifically for the less developed countries (James, 2006). Our result suggests that the "technology" measures of the Global Competitiveness Report are

indeed valid for developing countries. They also suggest that cutting-edge technology has little immediate impact on the advanced economies, but that technology diffusion in the less developed countries does have important economic benefits for these countries. Because our measure of technological competitiveness reflects conditions at about the year 2000, long-term benefits of innovations produced at that time may still accrue to the advanced economies in the future.

9. *Health.* Positive effects of intelligence on health at the individual level are well established (Gottfredson, 2004). If, as seems reasonable, a healthier work force has greater productivity, intelligence can promote economic growth by improving health. We used two country-level health indicators, life expectancy at birth and loss of disability-adjusted life years due to infectious diseases, to test the hypothesis that physical health mediates effects of intelligence on economic growth. We find that for both measures, intelligence is the strongest and most consistent predictor in regression models and path models. Although neither variable figures prominently in the growth regressions of Tables 3 and 4, in the path models of Table 5 we see a positive effect of life expectancy and a negative effect of infectious disease burden on lgGDP 2009 that is significant in the sample of all countries. One caveat is that reverse causation is possible, with better health permitting the development of higher intelligence. Eppig et al (2010) proposed that the relationship between infectious disease and country-level intelligence is due to a negative effect of infectious diseases on intelligence. However, the effects of parasites on intelligence are small in most studies (e.g., Berkman et al, 2002; Dickson et al, 2000). The rather pervasive effects of pre-existing intelligence on later health outcomes at the individual level (Gottfredson, 2004), and the relative ease with which most infectious diseases can be avoided by behavioral means, makes it more likely that this relationship is mainly due to an effect of intelligence on infectious disease.

10. *Fertility*. A negative relationship of fertility with intelligence, education and social status at the individual level is virtually universal in populations that have gone through the demographic transition

(Meisenberg, 2008b, 2010; Meisenberg and Kaul, 2010). This is in marked contrast to pre-transitional populations which usually show positive relationships between social status and fertility, especially in late medieval and early modern Europe (Clark and Hamilton, 2006; Razi, 1980; Skirbekk, 2008). The same is observed at the country level. In the current sample, the correlation of the total fertility rate (TFR) is -.838 with both schooling and intelligence (N = 134 countries). These values correspond closely with those obtained in an earlier study with different intelligence measures and a different country sample (Meisenberg, 2009). In path models, we find that predictors other than education and intelligence have only weak and inconsistent effects on the fertility rate. To some small extent, there may be reverse causation with small family size favoring the cognitive development of children. However, family size effects on intelligence are generally small and sometimes non-existent (Wichman et al, 2007; Zajonc and Sulloway, 2007). Therefore most of the observed relationship is most likely due to a fertility-reducing effect of high intelligence. High fertility is associated with slow economic growth in poor but not rich countries, confirming earlier findings reviewed in Headey and Hodge (2009). One reason for the growth-inhibiting effect of high fertility in the less developed countries is that the excess fertility is concentrated in the less educated sections of the population (Meisenberg, 2008b).

Interestingly, high population density no longer favors economic growth when TFR is in the model, as shown in Tables 3 and 4. The likely reason is that high population density is associated with low fertility (Meisenberg, 2009). High fertility is thought to impede economic growth by raising the youth dependency ratio and by keeping women out of the work force. In more advanced countries with a longer history of low fertility, however, low fertility has resulted in a high old age dependency ratio, which counteracts the growth-promoting effect of a lower youth dependency ratio. The results suggest that in developing countries, some of the economic benefits of high education and intelligence might be achievable by vigorous family planning programs, thus bypassing the need for costly efforts at improving education and intelligence.

11. *Crime*. A crime-reducing effect of high intelligence has been described at the individual-difference (Hirschi and Hindelang, 1977), county (Beaver and Wright, 2011), state (Bartels et al, 2010), and country levels (Lester, 2003). In our path models, intelligence is the only development indicator that is consistently associated with lower crime rates. Lower crime rates in turn tend to be associated with faster economic growth in prosperous but not poor countries. This effect seems to be robust, as it is seen both in the growth regressions of Table 4 and the path models of Table 5. It is not clear whether crime has a direct effect on economic growth or whether crime is merely an indicator of low "social capital." When a measure of business costs through *organized* crime from the Global Competitiveness Report is used, we find neither significant effects of intelligence on organized crime nor any negative effect of organized crime on economic growth (data not shown).

Historical context

Strong and consistent evidence shows that in all advanced societies for which data are available, intelligence has increased substantially during most of the 20th century, most likely by approximately 30 IQ points during the entire century (Flynn, 1987; Lynn and Hampson, 1986). This secular trend is known as the Flynn effect. Therefore the likely reason why high intelligence has promoted economic growth between 1975 and 2009 is that countries with high intelligence, measured mainly in the last third of the 20th or the first years of the 21st century, have experienced strong Flynn effects during the 20th century. Today, intelligence is no longer rising among young people in most of the advanced societies, and appears to be declining in some (Shayer and Ginsburg, 2009; Sundet et al, 2004; Teasdale and Owen, 2008). Conversely, Flynn effects of varying strength have recently been described for some developing countries including Sudan (Khaleefa et al, 2008), Brazil (Colom et al, 2006), Saudi Arabia (Batterjee, 2011), South Korea (te Nijenhuis et al, 2012), Turkey (Kagitcibasi & Biricik, 2011) and the Caribbean island nation of Dominica (Meisenberg et al, 2005). If there are substantial Flynn effects in developing countries during the 21st century while intelligence is stagnating or declining slowly in the most advanced societies, we can predict the emergence of a *negative* correlation between intelligence and economic growth during the 21st century.

When combined with our knowledge of the Flynn effect, the present results support a general theory of economic development in our time: In the wake of the Industrial Revolution, systems of mass education were established in 19th century Europe and North America which raised children's intelligence. Higher intelligence produced more innovation, further economic growth, and even better educational systems. These raised the intelligence of the next generation even further… This positive feedback between human intelligence and the economic and social conditions for the development of higher intelligence produced both Flynn effect and runaway economic growth.

The most likely reason why intelligence is no longer rising in the most advanced societies is that the biological limits of human intelligence are being approached in these countries, resulting in diminished cognitive returns to educational and other inputs. Because of a universal negative relationship of fertility with education and intelligence (Meisenberg, 2008b, 2010; Meisenberg & Kaul, 2010), the eventual result will not be stagnation, but a slow decline of intelligence over several generations. This is likely to have economic consequences, as shown by the recent demonstration that genotypic intelligence and the Flynn effect had distinguishable consequences for historic innovation rates (Woodley, 2012).

However, people in the less developed countries have not yet reached their cognitive limits. Future economic growth in today's less developed countries will most likely be accompanied by robust Flynn effects during the 21st century, as it was in the advanced economies of Europe, North America and East Asia during the 20th century. This era of the "Great Convergence" will continue until these nations reach their biological limits as well. Importantly, we do not know where exactly these limits may be. They are likely to be different for different nations. Above all we need to be aware that the sustained economic growth that we have experienced during the last two centuries is an historical anomaly that requires an explanation, and that changing human capital is the most important part of the explanation.

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