Cognitive Ability and Technology Diffusion: An Empirical Test

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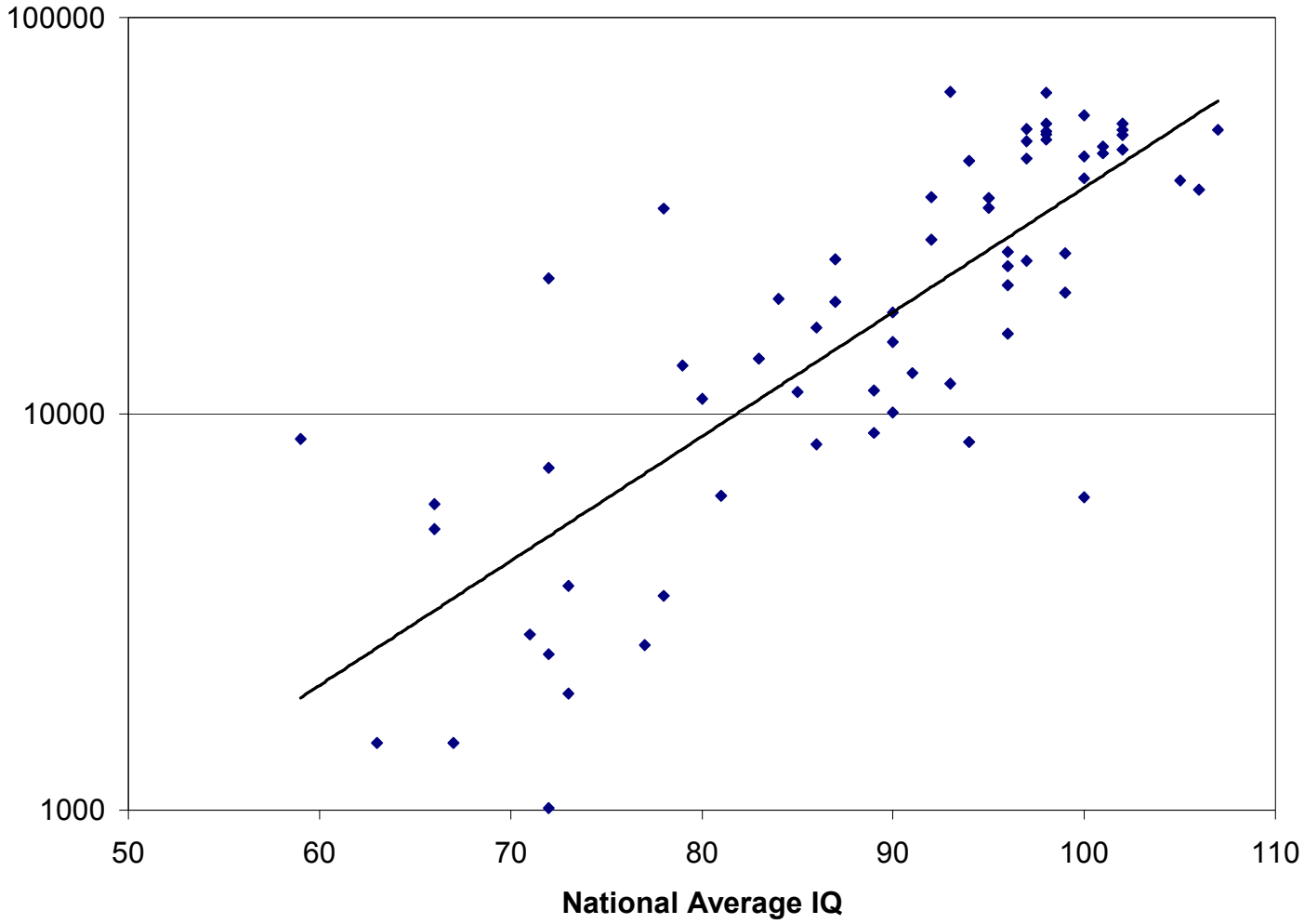
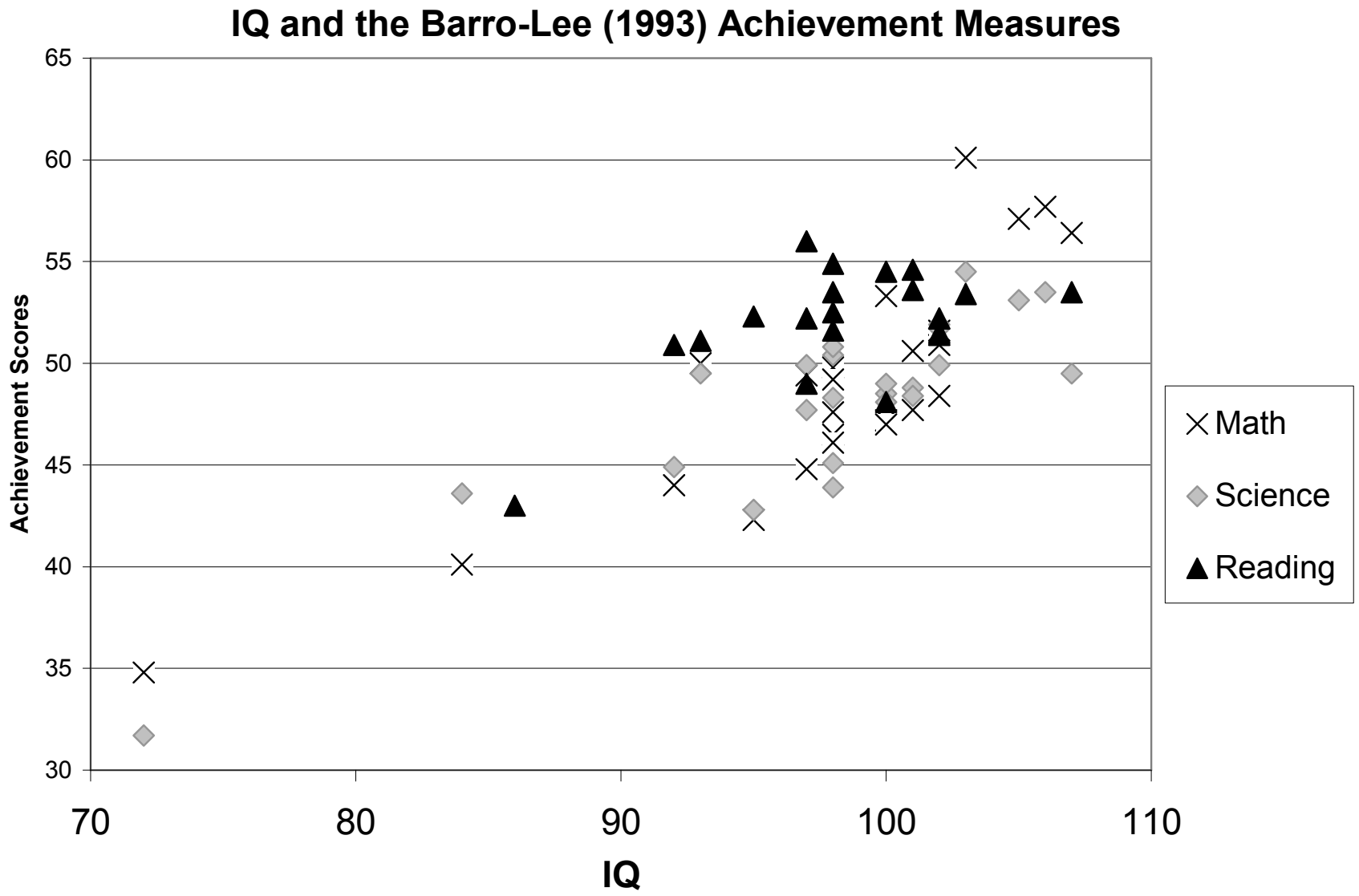
National Average IQ (Lynn and Vanhanen, 2006) and 2000 GDP per Worker (PWT)



R^2=64%; 1 IQ point ↔7.2% higher GDP per worker.
Robust to using only: Pre-1960, 1970, or 1980 IQ scores; nonverbal/culture-reduced tests.


IQ and the Barro-Lee (1993) Achievement Measures
Achievement Scores
65
60
55
50
45
40
35
30
70
80
90
100
110
IQ
Math
Science
Reading

The question addressed by this paper:

- Do scores on IQ tests do a better job predicting a nation's TFP growth than typical education measures?

The answer:

- Yes.

Why does this matter?

- A large literature looks at link between human capital and technology diffusion:
  - Nelson and Phelps (1966)
  - Benhabib and Spiegel (1994, 2005)
  - Banks (1994)
  - Howitt and Mayer Foulkes (2002)
  - Barro and Sala-i-Martin (1997)

But empirically, education performs poorly in empirical tests

Cognitive ability measures as a solution?

- A growing literature looks at the ability between *aggregate* cognitive ability and *aggregate* economic outcomes

- At micro level, cognitive ability has small impact on wages

- At cross-country level, differences in cognitive ability predicts large differences in aggregate productivity

- Why the difference? Perhaps ability impacts productivity through multiple channels:

  micro productivity (Jones and Schneider, 2007)
  time preference (Fredrick, JEP 2005; Warner/Pleeter AER 2000)
  political institutions (Jones, 2007)

  Perhaps technology diffusion as well?

What does IQ correlate with?

- Job performance ($\rho \approx 0.3$ to 0.5)

- IQ correlates positively with occupational prestige, educational attainment, creativity, physical health, mental health, longevity, suicide.

- Cerebral glucose metabolism ($\rho \approx -0.75$)

- Nerve conduction velocity between eye and brain ($\rho = 0.37$)

- Brain size ($\rho \approx 0.4$ at micro level)

- Useful metaphor: IQ as chip processing speed—not software

- Recommended: Deary, *Intelligence: A Very Short Introduction*
  Jensen, *The g Factor*

What IQ measures

- general knowledge
- verbal and spatial reasoning
- inductive and deductive reasoning
- quantitative reasoning
- verbal and memory retrieval fluency
- short-term and long-term memory
- reasoning and perceptual speed
- simple decision speed

Ex: Wechsler IQ test (WAIS-R) uses 13 subtests:

4: verbal comprehension
4: visual perception
3: working memory
2: processing speed
(Source: Deary et al., *Euro. J. Hum. Gen.*, 2006)

Are IQ tests biased against non-whites?

- Culturally loaded test items are not *relatively* more difficult for minority groups (Jensen, 1980, p. 528-529).

- Since the 1970's: No meaningful bias in IQ tests (Brown, Reynolds, & Whitaker, 1999; Jensen, 1980).

- IQ predicts non-test outcomes about equally well for non-whites (e.g., wages: Heckman et al., 1997).

- East Asian populations—in U.S. or East Asia—outperform whites on tests written by whites.

- Children of cross-racial adoptions (Asians or Africans) have IQ's similar to those of their genetic parents in U.S. or Europe.(N.B., small sample sizes)

- Brain size, electroencephalogram responses, and reaction-time tests maintain the same pattern across and within countries.

The Long-Run Rise in IQ

- Measured IQ's appear to rise an average of two to three points per decade, a phenomenon known as the *Flynn Effect*, after Flynn (1987).

- Possible explanations of the Flynn effect:
  --Genuine increase in the problem-solving ability of the population: *Health? Nutrition? TV?*

  --Teachers' greater tendency to "teach to the test."

- *No economist has empirically addressed this important subject*.
  Is Flynn Effect “nominal” or “real?”

- Flynn says it recently slowed/stopped in US.

Environmental Effects on IQ

All major IQ researchers agree: The environment impacts IQ.

Example: Childhood Nutrition

- Vitamins and minerals (Copenhagen Consensus, 2004). (Fogel, Stokey, Bhagwati, Schelling, et al.)

Previous work on IQ and productivity

- Lynn and Vanhanen, IQ and the Wealth of Nations (2002); Weede and Kampf (*Kyklos,* 2002); Volken (*Economica,* 2003); Weede (2004), Whetzel and McDaniel (2006), Ram (*Economics Letters,* 2007).

- 160 IQ tests, 81 countries over the last 100 years

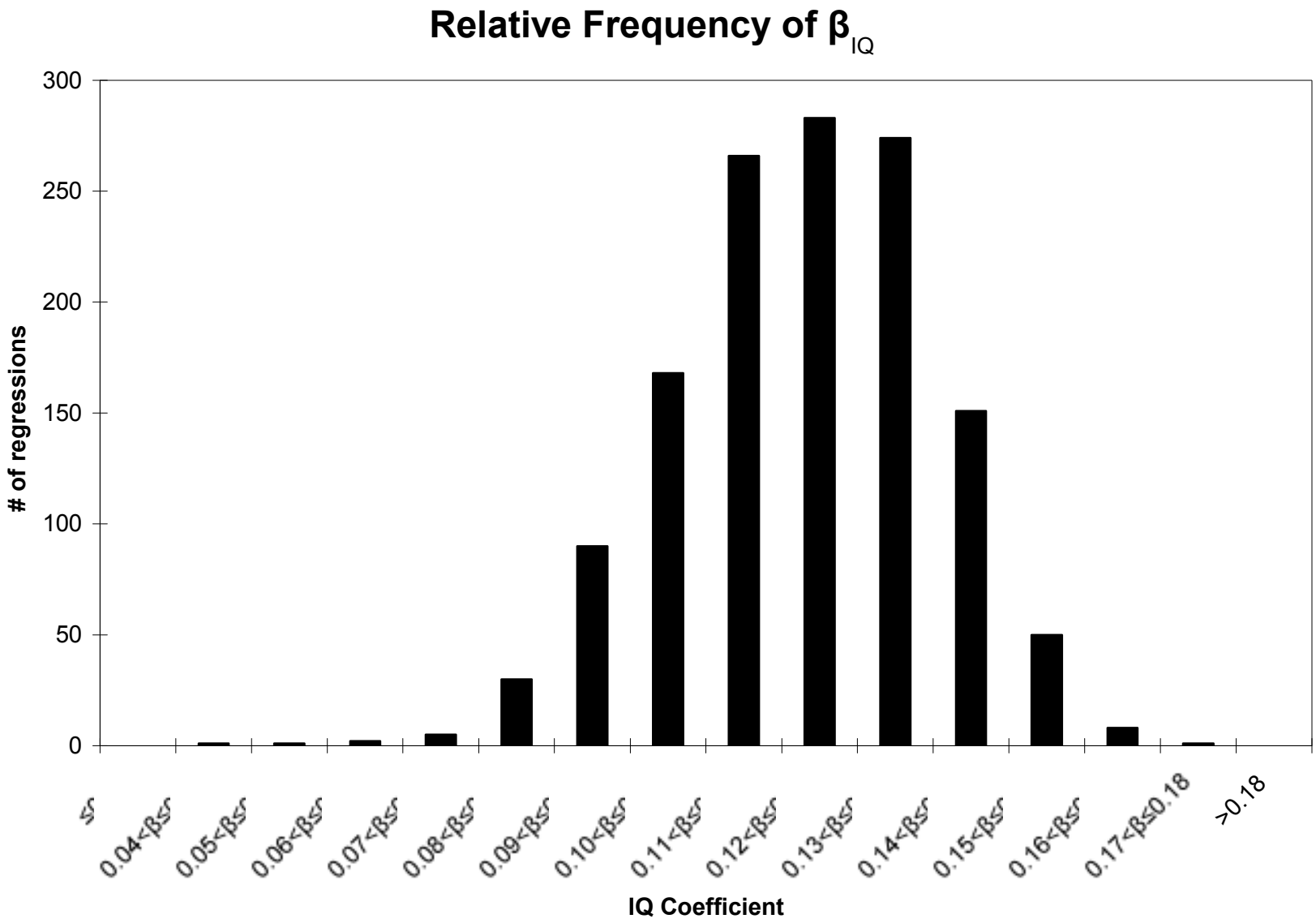
- ρ(IQ, *level* of Y/L) = 0.73

- Global mean IQ=90, Std Dev: 11. (UK Mean≡100, S.D.≡15)

"Intelligence, Human Capital, and Economic Growth"
Jones and Schneider, *J. Econ. Growth*, 2006

Goal: Stack the deck against IQ

- Ran 455 Solow/MRW-style growth regressions: All included IQ.
- Additional Controls: Combinations of 18 growth variables passing Sala-i-Martin et al.'s (AER 2004) Bayesian model averaging test
- IQ significant at 1% level in all 455 regressions
- Mean estimate: 1 IQ point → persistent 0.12% annual rise in Y/L
- In steady state: 1 IQ point → 6% rise in Y/L
- IQ dramatically more robust than education measures
- IQ also easily passed a Bayesian model averaging test: Even if you have a low prior that IQ is robust, the data should change your mind.


Relative Frequency of β IQ
300
250
200
150
100
50
0
# of regressions
0.04<β≤
0.05<β≤
0.06<β≤
0.07<β≤
0.08<β≤
0.09<β≤
0.10<β≤
0.11<β≤
0.12<β≤
0.13<β≤
0.14<β≤
0.15<β≤
0.16<β≤
0.17<β≤0.18
>0.18
IQ Coefficient

Variables passing Sala-i-Martin et. al's (AER 2004) robustness test:

Included in all 455 regressions:

1. log GDP per capita 1960 (log) -
2. Primary schooling 1960 +
3. Investment price −

Included 3 at a time:

4. East Asian Dummy +
5. Fraction of tropical area −
6. Population density coastal 1960's +
7. Malaria prevalence in 1960's −
8. Life expectancy in 1960 +
9. Fraction Confucian +
10. African dummy −
11. Latin American dummy −
12. Fraction GDP in mining +
13. Spanish colony −
14. Years open to trade +
15. Fraction Muslim +
16. Fraction Buddhist +
17. Ethnolinguistic fractionalization −
18. Government consumption share 1960's −

A benchmark model of diffusion
(Nelson-Phelps 1966)
Formalization of Gerschenkron (1962),
"The Advantages of Backwardness"

Simple verbal theory….
Worker skill impacts productivity growth in two ways:

α: By creating new ideas within your country

β: By helping your country adopt the ideas of the world leader

Mathemetically, we can write:

$$\%\Delta A_i = \alpha * h_i + \beta * h_i * (\text{distance from frontier})$$

$A_i \equiv$ TFP in country *i*; $h_i \equiv$ human capital in *i*

Two models of diffusion and why they matter

1. $\%\Delta A_i = \alpha h_i + \beta h_i (1 - \frac{A_i}{A_{leader}})$

   as $A_i \rightarrow 0$, $\%\Delta A_i \rightarrow \beta h_i$

poverty trap if $\alpha h_i + \beta h_i <$ frontier growth rate
(conditional convergence otherwise)

2. $\%\Delta A_i = \alpha h_i + \beta h_i (\frac{A_{leader}}{A_i} - 1)$

   as $A_i \rightarrow 0$, $\%\Delta A_i \rightarrow \infty$

   no poverty trap

Which wins?

In a model specification search,
Benhabib/Spiegel found model 1 fit best:

$$\%\Delta A_i = \alpha h_i + \beta h_i \left(1 - \frac{A_i}{A_{leader}}\right)$$

where h_i= measure of human capital,

A_x= TFP in country x

and Greek letters are estimated coefficients

- Key insight: if h_i is low, convergence is slow
  —perhaps absent.

Data

TFP growth and levels: Benhabib and Spiegel (B/S)
(*AER* 1994, *Handbook of Economic Growth* 2005)

IQ measures: Lynn and Vanhanen (2006)

Education measures: Barro and Lee (JME 1993, updated 2000)
Average years of attainment, age 25+ population,
Two measures: 1960 and average 1960-1995 (As in B/S)

Other variables: Sala-i-Martin, Doppelhofer, and Miller
(AER 2004)

Summary Statistics

	IQ	Est. IQ	Pre-70 IQ	log TFP60	log TFP95	TFP growth	Avg. Educ. 60	Avg. Educ. 60-95
Mean	88.4	86.4	87.0	0.39	0.85	1.3%	3.5	4.6
Median	88.5	86.5	88.0	0.41	0.92	1.3%	3.1	4.4
Maximum	108.0	108.0	105.0	1.33	1.86	4.3%	9.6	10.7
Minimum	64.0	64.0	61.0	-1.06	-1.02	-1.5%	0.1	0.4
Std. Dev.	11.5	11.8	12.9	0.49	0.65	1.2%	2.5	2.6
Skewness	-0.4	-0.2	-0.5	-0.33	-0.52	0.149	0.7	0.4
Kurtosis	2.4	2.1	2.2	2.79	2.51	3.591	2.6	2.3
Obs.	68	84	25	84	84	84	82	82

Note: "IQ" is the Lynn and Vanhanen estimate of the average IQ score in a country for which they have data. "Est. IQ" includes, in addition, interpolated values based on IQ estimates of geographically proximate countries. Lynn and Vanhanen show that such interpolations have high correlations with actual IQ scores. Years of Schooling from Barro-Lee (2000) (denoted "h" below). IQ data are from Lynn and Vanhanen (2006). TFP data are from Benhabib and Spiegel (2006).

Correlation Matrix

	IQ	Est. IQ	Pre-70IQ	log TFP60	log TFP95	TFP Growth	Avg. Educ. 1960	Avg. Educ. 60-95
IQ	1.00	1.00	0.90	0.51	0.85	0.67	0.68	0.74
Est. IQ	1.00	1.00	0.90	0.56	0.84	0.64	0.71	0.76
Pre-70IQ	0.90	0.90	1.00	0.58	0.77	0.60	0.73	0.76
log TFP60	0.51	0.56	0.58	1.00	0.76	0.00	0.75	0.73
log TFP95	0.85	0.84	0.77	0.76	1.00	0.65	0.76	0.82
TFP Growth	0.67	0.64	0.60	0.00	0.65	1.00	0.30	0.40
Avg. Educ. 1960	0.68	0.71	0.73	0.75	0.76	0.30	1.00	0.97
Avg. Educ. 60-95	0.74	0.76	0.76	0.73	0.82	0.40	0.97	1.00

Basic Regression Results

Dep. Var →	**log TFP95**						**TFP growth, 1960-1995**					
IQ	0.0454 ***			0.0319 ***			0.0663 ***			0.0960 ***		
est. IQ		0.0467 ***			0.0337 ***			0.0658 ***			0.0867 ***	
Pre-70 IQ			0.0456 ***			0.0262 **			0.057 **			0.074 **
h 1960				0.0767 ***	0.080 ***	0.1006 *				-0.204 ***	-0.1479 *	-0.118
N	68	84	25	66	82	24	68	84	25	66	82	24
R^2	72%	71%	59%	82%	79%	76%	45%	41%	36%	55%	45%	38%

Note: Standard errors in parentheses. *, **, and *** represent statistical significance at the 5%, 1%, and 0.1% levels, respectively.

"h" is the education level

Solovian Convergence Results

	Dependent Variable→	**TFP growth, 1960-1995**					
IQ		0.0944***			0.0937***		
est.IQ			0.0956***			0.0926***	
Pre-1970 IQ				0.737***			0.0749**
h 1960					0.0335	0.0645	0.101
log TFP 1960		-1.274***	-1.271***	-0.654	-1.636***	-1.639***	-1.58
N		68	84	25	66	82	24
R^2		68%	60%	42%	71%	63%	50%

Note: Standard errors in parentheses. *, **, and *** represent statistical significance at the 5%, 1%, and 0.1% levels, respectively.

Implicit model: $\Delta a_{i,t} = \alpha h_i - \beta a_{i,t-1}$

Benhabib-Spiegel Convergence Results

	Dep Var→	**TFP growth, 1960-1995**								
IQ		0.1009***			0.0940***			0.0886***		
est.IQ			0.1012***			0.0912***			0.0809***	
Pre-1970 IQ				0.0769**			0.0686*			0.0577*
IQ*log TFP 1960		-0.0150***	-0.0150***	-0.00766	-0.0161***	-0.0155**	-0.121	-0.0154**	-0.0142*	-0.0089
h60					0.1660	0.2163*	0.2986			
h60*logTFP60					-0.1106	-0.1374	-0.1825			
h 60-95								0.1758*	0.2556**	0.3541
h60-95*logTFP1960								-0.0981	-0.1382	-0.2031
N		68	84	25	66	82	24	66	82	24
R^2		70%	62%	42%	74%	65%	51%	75%	67%	55%

Note: Standard errors in parentheses. *, **, and *** represent statistical significance at the 5%, 1%, and 0.1% levels, respectively.

Robustness Tests

following B/S, using data from SDM, (AER 2004)

	Dep Var→	TFP growth, 1960-1995
IQ		0.1053 ***
IQ*log TFP 1960		-0.0227 ***
Tropics		0.1284
Sub-Saharan Africa		0.4230
Life Exp. 1960		0.0534 ***
Years Open		0.2574
Ethnolinguistic Fract.		0.0985
h60-95		-0.1235
h60-95*logTFP 1960		0.0121
N		48
R^2		89%

IQ is similarly robust if test includes:

-Estimated IQ (58 obs.)

-12 specifications using SDM's 67 variables 6 at a time in alphabetical order

(IQ t-stat ≈ 10)

Only significant SDM variables:

Life exp 1960 (+), Fertility(-), Schooling (+/-), Inflation (-), RevCoup(-)

IQ is not robust if:

Pre-1970 IQ is used (19 obs.)

N.B. Size of IQ and interaction terms change little from previous estimates

What about poverty traps? Recall:

$$\%\Delta A_i = \alpha IQ_i + \beta IQ_i\left(1 - \frac{A_i}{A_{leader}}\right)$$

If $\alpha IQ_i + \beta IQ_i <$ frontier TFP growth, country i will fall behind ***forever***.

Countries where $\alpha IQ_i + \beta IQ_i < 1.5\%$

Botswana	*Kenya*	*Niger*	*Uganda*
Cameroon	*Lesotho*	*Senegal*	*Zambia*
Centr. Afr. Rep.	*Malawi*	*South Africa*	*Zimbabwe*
Ghana	*Mali*	*Tanzania*	
Jamaica	*Mozambique*	*Togo*	

Includes every SSA country in sample plus Jamaica

All did worse than U.S. 1960-1995 except:
Botswana (a miracle economy, Acemoglu et al. 2001) and Zimbabwe (a near-tie)

IQ^*: 76

Other IQ→ Y/L channels?

- "Are Smarter Groups More Cooperative? Evidence from Prisoner's Dilemma Experiments, 1959-2003"(Jones, 2006)
- 100 SAT points↔5% rise in cooperation in repeated PD. Why? Patience, Perceptivity, and Altruism (Axelrod, 1984)
- Impatience (Warner and Pleeter, AER '01; Fredrick, JEP '06). Helps explain lower savings rates in poor countries—and higher cooperation in RPD's.
- IQ in the Production Function (Jones and Schneider, 2007) Higher wages can't explain vast differences in output—need some non-private-marginal-product-of-labor channel.

Conclusion

- Average intelligence differs across countries
- Correlates of intelligence (brain size, reaction time) easily verified by brain scans
- IQ scores are better proxies of human capital than education when predicting TFP growth
- As usual, IQ is remarkably robust across specifications
- Poverty traps are possible if cognitive abilities remain low

Q: Why *does* technology diffuse more quickly to high-IQ countries than to high-education countries?

Abstract

Recent economic research, including Hanushek and Woessmann (NBER working paper, 2007), Jones and Schneider (*Journal of Economic Growth*, 2006), and Ram (*Economics Letters,* 2006) has shown that cognitive ability scores are robustly associated with good economic performance. They invariably find that cognitive ability scores have vastly more predictive power than traditional schooling measures.

The question of *whether* intelligence tests and other standardized tests are robust predictors of growth has apparently been settled. The present paper, like the rest of my current research, turns to the question of why this is so. This paper focuses on the following question: How much of the cognitive ability/economic growth relationship is due to high-ability countries being better at absorbing ideas from the world's technology leader?

Benhabib and Spiegel (*JME* 1994, *Handbook of Economic Growth* 2005) estimated the technology diffusion model of Barro and Sala-i-Martin (*Journal of Economic Growth*, 1997); Benhabib and Spiegel used years of education as their measure of human capital, and found a modestly robust relationship that weakened considerably when additional control variables were added.

I, instead, use the database of IQ tests assembled by Lynn and Vanhanen (*IQ and Global Inequality*, 2006), and invariably find a robust relationship between national average IQ and the conditional rate of total factor productivity growth over the 1960-1995 period. In a horse race between IQ and education, national average IQ easily wins under all specifications. The results also hold even if only pre-1970 IQ scores are used.

In other robustness tests, I show whether other cross-country cognitive ability tests, such as those from Hanushek and Kimko (*AER* 2000) and Barro and Lee (*AER* 1996), are as robust as Lynn and Vanhanen's intelligence measures. I also point to the psychology literature demonstrating that while environmental effects can explain some of the IQ gap across countries, there is also some evidence in support of genetic sources for this gap. Accordingly, disentangling this nature-nurture question will likely be of increasing importance to growth economists in the future.

Arthur Jensen's book *The g Factor*, provides the best overview of this literature. Recent work along these lines (focusing more on rates of time preference than on cognitive ability) appears in economic historian Gregory Clark's forthcoming book, *A Farewell to Alms*, and in his working paper, "Genetically Capitalist?"

In all, the results strongly support the hypothesis that abstract tests of reasoning ability given to a random sample of the population can tell us much more about an economy's economic potential than measuring years of schooling. One can only hope that economists and other researchers will find ways to increase such test scores substantially in the world's poorest countries.