Understanding Educational Impacts:

The Role of Literacy and Numeracy Skills

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Introduction

- Substantial research on relationship between formal education and individual earnings
- Considerable evidence that schooling has a causal effect on earnings (Card, 1999, 2001)
- Large body of evidence on non-pecuniary impacts:
  - Recent surveys: Lochner (2011), Oreopoulos and Salvanes (2010)
  - Civic participation (Dee, 2004; Milligan, Moretti and Oreopoulos, 2004)
  - Health and longevity: mixed evidence (Lleras-Muney, 2005; Oreopoulos, 2007; Mazumder, 2008; Clark and Royer, 2013; Grossman, 2015)
  - Participation in crime (Lochner and Moretti, 2004)
  - Inter-generational impacts (Plug, 2004; Oreopoulos, Page and Stevens, 2006; Black, Devereux and Salvanes, 2005; Holmlund et al 2011)
  - Satisfaction with life (Oreopoulos, 2007)

Motivation

- However, little known about mechanisms

- Possible schooling mechanisms:
  1. Education enhances cognitive skills
  2. Education improves non-cognitive skills
  3. Education (via improved earnings) alters budget constraint
  4. Education alters preferences (eg more ‘forward looking’)

- **Objective of paper:** assess extent to which impacts arise because of impact of schooling on basic literacy & numeracy skills and their consequences for individual outcomes

Overview of Paper

- Study uses rich source of data that includes demographic and labour market information and results of cognitive skills tests (IALSS – Cdn component of Adult Literacy and Life Skills Survey)

- Data combine methods of educational testing with household survey techniques

- In IALSS 2003, skills were assessed in four domains:
  - Prose literacy, Document literacy, Numeracy, Problem-solving

- Provide measures of the skills of a representative sample of the adult population

- Key feature: these are skills used in daily activities – measures of job- and life-relevant skills, not ability measures

- eg: Document literacy: skills required to find and use information contained in text formats such as job applications, payroll forms, bus schedules, graphs

- Numeracy: “the knowledge and skills required to effectively manage and respond to the mathematical demands of diverse situations”

- Skills are assessed in English or French – i.e. correspond to “useable” skills in Canadian labour market

Skills and Earnings: Interpretive Framework

- Simple framework builds on Welch (1969) and Rosen (1974).

- Hedonic model in which earnings are determined by the skills an individual possesses and the prices of those skills.

- Abstracting from other influences on earnings, individual earnings are a function of the skills an individual possesses and puts into use:

- $E_i = f(G_i^1, G_i^2, G_i^3) + e_i$ (1)

- where E_i are earnings for individual i, G_i^k is the amount of skill k that person i supplies in the market, and e_i is independent of the skills.

- Typically, we do not observe the skills but we do observe some of the inputs that generate them. They enter via skill production functions:

- $G_i^k = h_k (edn_i , exp_i , v_{ki})$ (2)

- where *k* indexes the skill type, *edn* corresponds to education, *exp* is years of work experience (or age) and v_k is an ability specific to the production of the *k*th skill.

- If we do not observe the G_i^k s directly, we can obtain an estimating equation by substituting equation 2) into 1).

- This yields a reduced form specification for earnings as a function of education and experience.

- The coefficient on a covariate *x* such as education (the “return” to schooling) reflects the combination of how that input contributes to production of each skill and how those skills contribute to earnings.

$$5)\ \frac{\partial E}{\partial x} = \frac{\partial f}{\partial G^1} * \frac{\partial h_1}{\partial x} + \frac{\partial f}{\partial G^2} * \frac{\partial h_2}{\partial x} + \frac{\partial f}{\partial G^3} * \frac{\partial h_3}{\partial x}$$

What if some skills are observed?

- If we observe the cognitive skills G^1, we get a quasi-reduced form earnings regression that includes G^1 (the vector of cognitive skills), experience and education.

$$E_i = g^*(G_i^1, edn_i, exp_i, v_{ki}) + u_i \quad (6)$$

- The quasi-reduced form parameters on *edn* and *exp* now reflect the impact of education and experience on the production of skills other than the observed cognitive skills.

$$9)\ \frac{\partial g^*}{\partial x} = \frac{\partial f}{\partial G^2} * \frac{\partial h_2}{\partial x} + \frac{\partial f}{\partial G^3} * \frac{\partial h_3}{\partial x}$$

- The difference between the reduced form and quasi-reduced form estimates measures the contribution of the observed skill to the total “return” to schooling

- Taking difference between RF (equation 5) and QRF (equation 9) yields:

$$\frac{\P f}{\P x} - \frac{\P g^*}{\P x} = \frac{\P f}{\P G^1} * \frac{\P h}{\P x} \quad (10)$$

- I.E. the fraction of the impact of schooling S on earnings due to influence of S on literacy skills and their impact on earnings

- Thus comparing coefficient on S in RF earnings eqn to that in QRF eqn measures role of literacy skill generation in impact of schooling on earnings

DATA: International Adult Literacy and Skills Survey

- IALSS sample size: 23,038
- Drop immigrants, aboriginals, students => 14,666 obs
- Rich data on education (eg years of schooling, attainment, prov of HS), parental characteristics, exact date of birth
- Earnings sample drops self-employed, unemployed, non-participants, wage outliers: 7569 obs
- Correlation among test scores:
  - Prose and Document .96
  - Document and Numeracy .92
  - Document and Problem solving .92
- Factor analysis: one principal component placing essentially equal weight on all four scores
- We focus on average score, but report results for individual skills

Compulsory schooling laws

- We use minimum School Leaving Age (SLA) and maximum School Entry Age (SEA) as IVs for schooling S
- Identification assumes variations in SLA and SEA over time and across provinces induced changes in S that are unrelated to ‘unobserved ability’ factors
- Compiled data from provincial statutes and date of proclamation or ascension from provincial regulations
- Note changes often implemented during year (e.g. July 1 or Sept 1)

Compulsory schooling laws

- Using exact date of birth, province of HS and implementation date allows a more precise match of CSL to affected individuals (compared to previous studies)

- EG can exploit rules that say "until end of June in year turn 16" versus just "16"

- Use main and most basic SLA and SEA when there are exemptions or other requirements

- Use urban SLA and SEA if both urban and rural specified

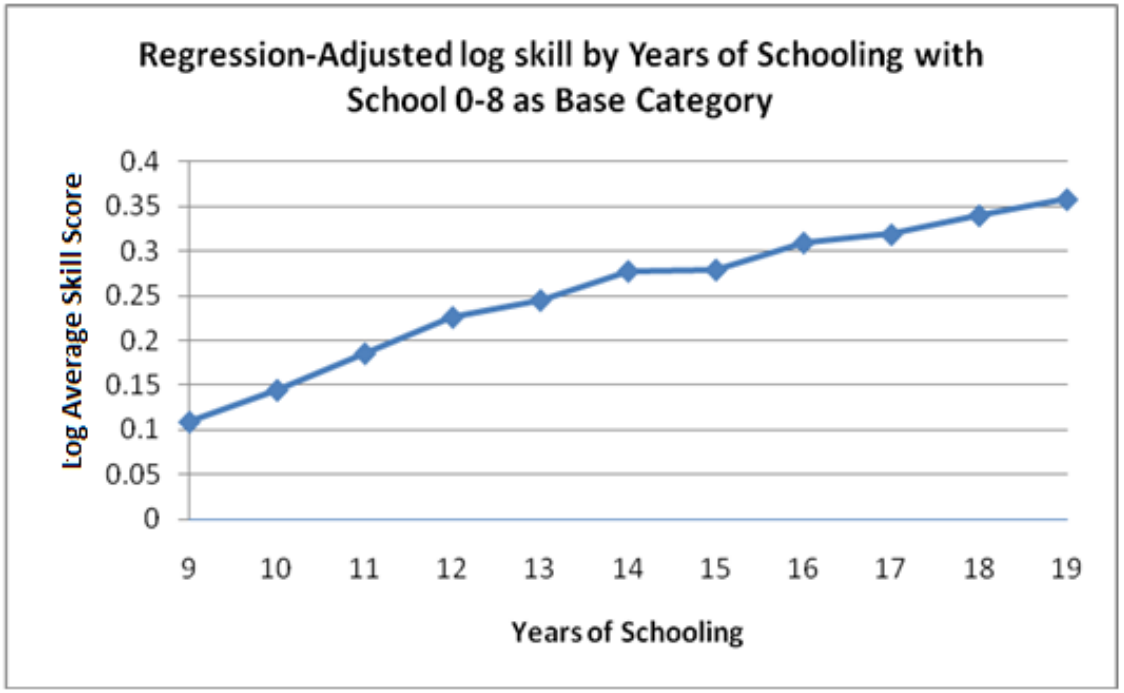
Outline of empirical results

- Evidence on causal impact of schooling on basic literacy and numeracy skills (skill production functions)
- RF and QRF earnings equations, i.e. with and without controls for basic cognitive skills
- Quantile regressions – to see if impacts of education, experience and skills vary across earnings distribution (in Appendix)

Cognitive skills and schooling

- Figure 1 shows partial relationship controlling for gender, age, age squared, parental characteristics, province, urban/rural
- Slightly concave especially after 16 years
- Diminishing returns not surprising given these are basic skills
- We drop those with S > 16 and specify linear relationship

Figure 1


Regression-Adjusted log skill by Years of Schooling with School 0-8 as Base Category
Log Average Skill Score
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
9
10
11
12
13
14
15
16
17
18
19
Years of Schooling

Determinants of skills II

- Table 2a reports log skills regressions using average skill score
- Small gender difference
- Essentially no relationship between skills and age in cross-section (e.g. impact of 1 year at age 30 = - 0.4%, at age 50 = -0.7%)
- G&R (2003) also found no relationship between literacy skills and age or experience with IALS 94 data
- Strong relationship with formal schooling
- Results for individual cognitive skills similar, though sign of gender coefficient varies across skills (Table 2b shows IV estimates)
- Partial impact of S largest for Doc literacy & Numeracy

Addressing potential omitted variables bias

- Column 2 (OLS2) adds controls for parental characteristics
- Parental education only matters if parents dropouts or parental education unknown (OLS2)
- Other parental influences (occupation, immigrant, mother working) minor
- Column 3 adds proxies for unobserved ability
- Ease of learning mathematics in high school
- Modest declines in coefficient on schooling in columns 2 and 3
- IV1 uses SLA as IV, matched using DOB and province of HS
- IV2 uses SLA and SEA, matched using DOB and province of birth
- First stage results in Table 3

Table 2a: Log of Average Skill Score Regressions

Variable	OLS1	OLS2	OLS3	IV1	IV2
Years of Schooling	0.036*** [0.001]	0.031*** [0.001]	0.028*** [0.001]	0.073*** [0.012]	0.084*** [0.012]
Female	-0.012** [0.005]	-0.010** [0.005]	-0.007 [0.005]	-0.024*** [0.007]	-0.027*** [0.007]
Age	0.003*** [0.001]	0.006*** [0.001]	0.006*** [0.001]	-0.001 [0.002]	-0.003 [0.002]
Age Squared	-0.007*** [0.001]	-0.009*** [0.001]	-0.009*** [0.001]	0 [0.003]	0.002 [0.003]
Mother's Education					
Less than High School		-0.040*** [0.006]	-0.043*** [0.006]	-0.008 [0.012]	0.001 [0.013]
Some Post Secondary		0 [0.007]	-0.002 [0.007]	-0.015 [0.010]	-0.019* [0.011]
BA or More		0.012 [0.012]	0.01 [0.011]	0.007 [0.015]	0.005 [0.016]
None Reported		-0.066*** [0.011]	-0.068*** [0.011]	-0.011 [0.019]	0.004 [0.021]

Father's Education					
Less than High School		-0.026***	-0.024***	0.008	0.017
		[0.007]	[0.007]	[0.013]	[0.014]
Some Post Secondary		0.002	0.004	-0.007	-0.009
		[0.008]	[0.008]	[0.010]	[0.011]
BA or More		0.018*	0.024***	-0.005	-0.011
		[0.009]	[0.009]	[0.014]	[0.015]
None Reported		-0.047***	-0.045***	0.005	0.019
		[0.011]	[0.011]	[0.019]	[0.020]
Immigrant Mother		0.006	0.005	-0.013	-0.019
		[0.008]	[0.008]	[0.011]	[0.012]
Immigrant Father		0.016**	0.018**	0.004	0
		[0.008]	[0.007]	[0.010]	[0.011]
Good Math Grades			0.025***		
			[0.006]		
Teachers Too Fast			-0.026***		
			[0.006]		
Observations	12370	12370	12370	12370	12370

LIML Estimates

- LIML provides small sample correction for bias in TSLS
- Bias especially likely if instruments weak and many over-identifying restrictions
- Results for Yrs schooling coefficient:

LIML Estimates- Literacy

Variable	OLS2	IV1	LIML1	IV2	LIML2
Years of Schooling	0.031***	0.073***	0.075***	0.084***	0.096***
	[0.001]	[0.012]	[0.012]	[0.012]	[0.017]
Observations	12370	12370	12370	12370	12370

Table 3: First Stage Results for Years of Schooling

Variable	IV1	IV2
CSLA>=15 & CSLA<16	0.630***	0.494***
	[0.113]	[0.119]
CSLA>=16	0.578***	0.479***
	[0.125]	[0.133]
CSEA=5 or 6		0.222
		[0.179]
CSEA=7		0.389**
		[0.173]
Female	0.316***	0.319***
	[0.075]	[0.075]
Age	0.162***	0.158***
	[0.012]	[0.012]
Age Squared	-0.193***	-0.188***
	[0.012]	[0.013]
Mother's Education		
Less than High School	-0.740***	-0.729***
	[0.111]	[0.112]
Some Post Secondary	0.361***	0.364***
	[0.117]	[0.117]
BA or More	0.135	0.14
	[0.173]	[0.172]
None Reported	-1.313***	-1.293***
	[0.188]	[0.188]

Father's Education		
Less than High School	-0.809***	-0.818***
	[0.109]	[0.109]
Some Post Secondary	0.220*	0.207
	[0.129]	[0.129]
BA or More	0.564***	0.557***
	[0.147]	[0.147]
None Reported	-1.252***	-1.262***
	[0.170]	[0.169]
Immigrant Mother	0.446***	0.435***
	[0.123]	[0.123]
Immigrant Father	0.241**	0.231*
	[0.123]	[0.123]
Observations	12370	12370
R-squared	0.27	0.27
First Stage F-Statistics	15.8	10.0

Earnings, schooling and skills

- Earners sample younger, better educated
- IV1 uses SLA and SEA as IV for years of schooling S
- IV2 uses SLA, SEA and province of HS plus province of HS fully interacted with Age as IVs for S and Ave Lit
- Rationale for Prov of HS instrument: Different levels of resources applied to schooling in different provinces for different cohorts will lead to different levels of school quality for otherwise identical individuals
- All regressions include controls for province of residence and urban/rural

Figure 2

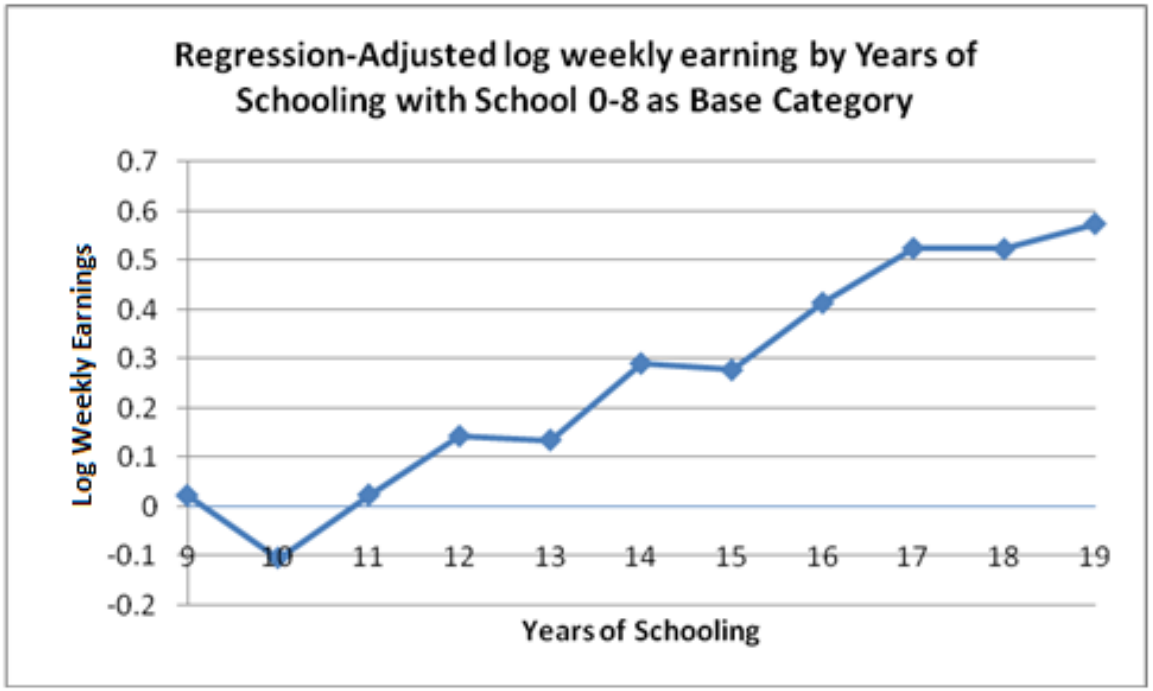

Regression-Adjusted log weekly earning by Years of Schooling with School 0-8 as Base Category
Log Weekly Earnings
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
9
10
11
12
13
14
15
16
17
18
19
Years of Schooling

Table 4: Earnings Regressions

Variable	OLS1	OLS2	IV1	IV2	IV2
Years of Schooling	0.085***	0.070***	0.089***	0.084***	0.054***
	[0.004]	[0.005]	[0.026]	[0.005]	[0.015]
Female	-0.414***	-0.411***	-0.416***	-0.414***	-0.408***
	[0.024]	[0.023]	[0.026]	[0.024]	[0.024]
Experience	0.067***	0.066***	0.067***	0.067***	0.065***
	[0.004]	[0.004]	[0.006]	[0.004]	[0.004]
Experience Squared	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Average Literacy Score		0.003***			0.005**
		[0.000]			[0.003]
Constant	4.657***	4.115***	4.610***	4.670***	3.548***
	[0.082]	[0.115]	[0.322]	[0.085]	[0.553]
Observations	7569	7569	7569	7569	7569
R-squared	0.39	0.41	0.39	0.39	0.39
First Stage F-Statistics					
Years of Schooling			20.4	139.7	139.7
Average Literacy Score					16.8

LIML estimates

- Overall, very similar to corresponding TSLS estimates:

LIML Estimates- Earnings

Variable	OLS		IV1	LIML1	IV2		LIML2	
Years of Schooling	0.085***	0.070***	0.089***	0.089***	0.084***	0.054***	0.084***	0.031
	[0.004]	[0.005]	[0.026]	[0.028]	[0.005]	[0.015]	[0.005]	[0.039]
Average Literacy Score		0.003***				0.005**		0.009
		[0.000]				[0.003]		[0.007]
Observations	7569	7569	7569	7569	7569	7569	7569	7569

Cognitive skills and earnings

- Introducing cognitive skills reduces schooling coefficient by 18% (OLS) to 35% to 40% (IV).

- Since cognitive skills do not increase with age, positive association between earnings and experience must be due to other factors

- Impact of cognitive skills on earnings is substantial. A 25 point increase in skills (half a standard deviation) is associated with an earnings increase equivalent to 1 (OLS) to 2 (IV) extra years of schooling

Conclusions

- Education has a substantial causal effect on basic literacy and numeracy skills. First evidence of such impacts for adult population.
- IV estimates suggest each year of school raises skills by 7% to 8%, or about 1/7 to 1/6 of a std deviation
- Indeed, formal schooling is the dominant determinant of these basic cognitive skills
- Finding runs counter to view that family background is key influence
- Parental education has a modest impact, but only matters (if at all) for parents < HS grad

Conclusions (cont'd)

- Suggests main influence of family background is on amount and quality of schooling, not directly on basic skills

- Basic literacy and numeracy skills account for about 18% (OLS) to 35-40% (IV) of the returns to schooling

- Cognitive skills have substantial effects on earnings: a 25 point increase in skills (1/2 std dev) has impact equivalent to 1 (OLS) to 2 (IV) extra years of schooling

Appendix

- Individual skill score regressions (Table 2b)

- Quantile regressions

Table 2b: Individual Skill Score Regressions with CSLA Instrument

Variable	Log Prose Score	Log Document Score	Log Numeracy Score	Log Problem Solving Score
Years of Schooling	0.070***	0.085***	0.070***	0.069***
	[0.012]	[0.014]	[0.013]	[0.012]
Female	0.011	-0.029***	-0.068***	-0.011
	[0.007]	[0.008]	[0.007]	[0.007]
Age	0	-0.003	0.001	-0.002
	[0.002]	[0.003]	[0.002]	[0.002]
Age Squared	-0.001	0.001	-0.003	0.001
	[0.003]	[0.003]	[0.003]	[0.002]
Mother's Education				
Less than High School	-0.003	0.002	-0.011	-0.019
	[0.012]	[0.014]	[0.013]	[0.012]
Some Post Secondary	-0.011	-0.026**	-0.011	-0.013
	[0.010]	[0.012]	[0.011]	[0.010]
BA or More	0.014	-0.002	0.006	0.005
	[0.015]	[0.016]	[0.019]	[0.014]
None Reported	0	-0.003	0.007	-0.046**
	[0.020]	[0.023]	[0.021]	[0.019]

Father's Education				
Less than High School	0.002	0.012	0.006	0.012
	[0.013]	[0.015]	[0.015]	[0.013]
Some Post Secondary	-0.012	-0.005	-0.011	0.001
	[0.010]	[0.011]	[0.012]	[0.010]
BA or More	-0.005	-0.006	-0.006	-0.003
	[0.014]	[0.016]	[0.015]	[0.014]
None Reported	0.009	0.019	-0.01	0.003
	[0.020]	[0.022]	[0.022]	[0.019]
Immigrant Mother	-0.01	-0.019	-0.013	-0.012
	[0.011]	[0.013]	[0.013]	[0.012]
Immigrant Father	0.004	0.008	0.002	0
	[0.010]	[0.012]	[0.012]	[0.010]
Constant	4.801***	4.690***	4.789***	4.848***
	[0.119]	[0.138]	[0.127]	[0.115]
Observations	12370	12370	12370	12370

Quantile regressions

- Quasi-reduced form earnings equation

$$6)\ E_i = g^*(G_i^1,\ yrs_i,\ \exp_i,\ \theta_i) + \varepsilon_i$$

- Partial derivative of 6) with respect to cognitive skills could vary with unobservables => quantile regressions

- These provide information on derivatives of earnings with respect to observables at different values of unobservables that generate conditional earnings quantiles

Quantile regressions

- Table 5 shows estimates at 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} quantiles
- Returns to schooling and experience decline across quantiles
- Coefficient on skills approximately constant across quantiles
- Suggests cognitive skills do not interact with unobserved abilities or skills in generating earnings

Table 8: Quantile Earnings Regressions

	10th Quantile	25th Quantile	Median	75th Quantile	90th Quantile
Female	-0.48***	-0.46***	-0.36***	-0.36***	-0.36***
	(0.048)	(0.032)	(0.020)	(0.021)	(0.032)
Years of Schooling	0.079***	0.065***	0.069***	0.067***	0.057***
	(0.011)	(0.0065)	(0.0041)	(0.0042)	(0.0069)
Experience	0.088***	0.084***	0.059***	0.050***	0.042***
	(0.0063)	(0.0041)	(0.0025)	(0.0024)	(0.0036)
Experience Squared	-0.0015***	-0.0015***	-0.001***	-0.0008***	-0.0006***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Average Literacy Score	0.0022***	0.0032***	0.0029***	0.003***	0.0028***
	(0.0007)	(0.0004)	(0.0003)	(0.0003)	(0.0005)
Constant	3.33***	3.67***	4.26***	4.62***	5.12***
	(0.19)	(0.12)	(0.083)	(0.079)	(0.13)
Observations	7768	7768	7768	7768	7768