Signaling and Employer Learning with Instruments

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Presentation at Joe-Fest 2018
September 7, 2018

Motivation

"... there is little in the data that supports Job Market Signaling as an explanation for the observed returns to schooling."
Lange and Topel (2006)

"The Case against Education: Why the Education System Is a Waste of Time and Money"
Caplan (2018)

Employer Learning and Signaling

Employer Learning (EL)

- natural assumption when agents face incomplete information.
- allows disentangling human capital and signaling if combined with (strong) auxiliary assumptions.

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EL with “hidden” productivity correlate

- implemented using AFQT score on NLSY1979.
- Farber and Gibbons (1996): evidence for EL.
- Altonji and Pierret (2001): evidence for statistical discrimination using schooling.
- Altonji and Pierret (1998), Lange (2007): learning is rapid so that returns to signaling are low.

Our Paper

- What IV estimates identify depends on whether employers observe the instruments.
  - “hidden” vs. “transparent” instruments
  - testable if combined with a hidden correlate.

Our Paper

- What IV estimates identify depends on whether employers observe the instruments.
  - “hidden” vs. “transparent” instruments
  - testable if combined with a hidden correlate.
- Implement using Norwegian administrative data:
  - males born 1950–1980 with earnings from 1967–2014
  - years of schooling, **IQ test score.**
  - IV from **cohort-locality variation in change to compulsory schooling.**

Results

1. Strikingly similar patterns in Norway and in NLSY.
2. Private returns > Social returns.
3. Employer learning is fast.
4. Social return $\approx$ 4/5 of private return to schooling.

Outline

Model of Employer Learning

Estimating EL models: Correlates and Instruments

Empirical Setting

Evidence on Private and Social Returns to Education

The Economy

- Wages = expected productivity given employers' information.
  - Labor markets are perfectly competitive
  - Symmetric EL
  - Spot markets
- One-shot schooling prior to starting work.
- No external effects on productivity.

The Economy

Log output of worker i with experience t is

$$\psi_{it} = \beta_{ws} S_i + \beta_{wq} Q_i + A_i + H(t) + \varepsilon_{it}$$

- (S_i, Q_i) are correlates observed by employers.
- A_i is ability unobserved by employers.
- ε_{it} is an independent period-specific productivity shock

Employer's Information Set

Output ψ_{it} is equivalent to a noisy signal of A_i:

$$\xi_{it} = A_i + \varepsilon_{it}$$

Employer's information set: $\mathcal{E}_{it} = (S_i, Q_i, \xi_i^t)$ with $\xi_i^t \equiv \{\xi_{i\tau}\}_{\tau<t}$.

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Wages equal ***expected*** productivity given information $\mathcal{E}_{it}$:

$$W_{it} = \mathbb{E}\left[\exp(\psi_{it}) \mid S_i, Q_i, \xi_i^t\right]$$

Market Wages

Assuming $(S_i, Q_i, A_i, \varepsilon_{it})$ are normal:

$$\ln W_{it} = \beta_{ws} S_i + \beta_{wq} Q_i + \mathbb{E}\left[A_i \mid S_i, Q_i, \xi_i^t\right] + \underbrace{\tilde{H}(t)}_{\equiv 0}$$

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with

$$\mathbb{E}\left[A_i \mid \mathcal{E}_{\text{it}}\right] = \theta_t \mathbb{E}\left[A \mid S, Q\right] + (1 - \theta_t)\, \bar{\xi}^t$$

$$\mathbb{E}\left[A \mid S, Q\right] = \phi_{A|S} S + \phi_{A|Q} Q$$

$$\theta_t = \frac{1 - K_1}{1 + (t-1) K_1};\ K_1 = \frac{\sigma_0^2}{\sigma_0^2 + \sigma_\varepsilon^2}$$

Social Returns to Education

Assume linear causal effects of schooling on (Q, A):

$$\begin{aligned} Q &= \delta^{Q|S} S + \tilde{Q} \\ A &= \delta^{A|S} S + \tilde{A} \end{aligned}$$

Then,

$$\begin{aligned} \psi_{it} &= \left(\beta_{ws} + \beta_{wq}\delta^{Q|S} + \delta^{A|S}\right) S + \beta_{wq}\tilde{Q} + \tilde{A} + \varepsilon_{it} \\ &= \delta^{\psi|S} S + \tilde{\psi}_{it} \end{aligned}$$

Define social return to schooling $\delta^{\psi|S}$ = causal effect on log productivity irrespective of who this accrues to.

Private Returns to Education

Define the private return to schooling $\delta_t^{W^e|S}$ = causal effect on log earnings at t an individual can expect at t=0.

Substituting and collecting terms, we get

$$\delta_t^{W^e|S} = \delta^{\psi|S} + \theta_t \left(\underbrace{\phi_{A|S} + \phi_{A|Q}\delta^{Q|S}}_{\text{Inference of A}} - \underbrace{\delta^{A|S}}_{\text{Causal on A}} \right)$$

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OLS Estimates of Mincer Equations

Standard OLS estimates of Mincerian returns to schooling result in

$$b_{OLS,t} = \delta^{\psi|S} + \frac{cov\left(\beta_{wq}\tilde{Q} + \tilde{A}, S\right)}{var\left(S\right)}$$

- Omitted Variable Bias does not vanish with experience.
- Standard reason offered for instrumenting.

Exploiting a Productivity Correlate

Farber and Gibbons (1996), Altonji and Pierret (1998, 2001), Lange (2007)

If researchers have access to a productivity correlate Z_{it} that employers do not, then:

$$\mathbb{E}\left[lnW_{it}|S, Z, t\right] = \theta_t \mathbb{E}\left[lnW_{i0}|S, Z\right] + (1 - \theta_t)\,\mathbb{E}\left[lnW_{i\infty}|S, Z\right]$$

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- Coefficient on Z increases with t.
- If $cov\,(S,Z) > 0$, then coefficient on S declines.
- How rapidly $\mathbb{E}\left[lnW_{it}|S,Z,t\right]$ converges to $\mathbb{E}\left[lnW_{i\infty}|S,Z\right]$ identifies K_1.
- Coefficients themselves are difficult to interpret in terms of fundamentals.

Instrumental Variables

Consider a binary instrument $D_i \in \{0, 1\}$ that satisfies the standard assumptions:

1. (Conditional independence): $(Q_i, A_i) \perp D_i \mid S_i$.
2. (First Stage): $E[S_i|D_i = 0] \neq E[S_i|D = 1]$.
3. (Monotonicity): $S_i(D_i = 1) \geq S_i(D_i = 0)$ for all i.

The Wald Estimator

$$plim\left(b_{IV,t}\right) = \frac{\mathbb{E}\left[lnW_{it}|D=1,t\right] - \mathbb{E}\left[lnW_{it}|D=0,t\right]}{\mathbb{E}\left[S|D=1\right] - \mathbb{E}\left[S|D=0\right]}$$

and because of learning

$$plim\left(b_{IV,t\rightarrow\infty}\right) = \frac{\mathbb{E}\left[\psi_i|D=1\right] - \mathbb{E}\left[\psi_i|D=0\right]}{\mathbb{E}\left[S|D=1\right] - \mathbb{E}\left[S|D=0\right]} = \delta^{\psi|S}$$

For large t, IVs identify the social returns.

What about t<∞?

- For $t < \infty$, the interpretation of $b_{IV,t}$ depends on information available to employers.
- Distinguish two cases:
  - "transparent instrument": $D_i \in \mathcal{E}_{it}$
  - "hidden instrument": firms are unaware of the instrument $D_i \notin \mathcal{E}_{it} \therefore W_{it} \perp D_i | S_i, Q_i, \xi_i^t$.

Transparent Instrument

When the instrument is correctly priced, we have

$$\mathbb{E}\left[lnW_{it}|D\right] = \mathbb{E}\left[\delta_{\psi|S}S + \tilde{\psi}|D\right] = \delta^{\psi|S}\mathbb{E}\left[S|D\right]$$

$\Rightarrow$

$$b_{IV,t} = \frac{\mathbb{E}\left[lnW_{it}|D=1\right] - \mathbb{E}\left[lnW_{it}|D=0\right]}{\mathbb{E}\left[S|D=1\right] - \mathbb{E}\left[S|D=0\right]} = \delta^{\psi|S}$$

Hidden Instrument

Hidden instrument identify the private return to schooling:

$$b_{IV,t} = \delta^{\psi|S} + \theta_t \left(\phi_{A|S} + \phi_{A|Q}\delta^{Q|S} - \delta^{A|S}\right)$$

Allows estimating:

- the private returns throughout the life-cycle.
- the social returns as $b_{IV,t\to\infty}$.
- the Speed of Learning K_1 using the convergence of $b_{IV,t}$ to $b_{IV,\to\infty}$.

Examples from the Literature

Hidden?

- Draft lottery Number and Year of Birth (Angrist and Krueger (1992)).
- Elimination of Social Security Student Benefit in 1982 interacted with family background (Dynarski (2003)).
- Grade-cutoff and college admission (Zimmermann (2014)).
- Experimentally induced local variation in compulsory attendance laws (Meghir and Palme (1999)).

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Transparent?

- Distance to college (Card (1995))
- Labor market conditions (Cameron and Heckman (1998), Carneiro, Heckman, and Vytlacil (2005), Cameron and Taber (2004))

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Empirical Setting

Evidence on Private and Social Returns to Education

Ideal data set would ...

- large N across many years of experience.
- reliable measures of earnings and schooling.
- include a instrument that can be confidently classified as “hidden” or “transparent”.
- contain a correlate of productivity that is clearly unobserved by employers.

Our data - Norway

- Drawn from registry databases maintained by Statistics Norway
  - 732,163 males born between 1950 and 1980
  - ca 14.8 Mio earnings observations from 1967-2014
  - cohort of birth, history of residence, schooling
- Merged in: ability test scores from draft boards for Norwegian Armed Forces.
  - not shared with conscripts
  - administered around 18th birthday
  - correlation with schooling in our data: 0.5

OLS Regression Coefficients on Schooling and IQ

	(1)	(2)	(3)
Dependent Variable:		**Log-Annual Earnings**	
Years of Schooling	0.068***	-	0.056***
	(0.000)		(0.000)
IQ Test Score (St.dev)	-	0.091***	0.057**
		(0.000)	(0.001)
Controls:		***experience profile (dummies)***	
R^2	0.67	0.63	0.71

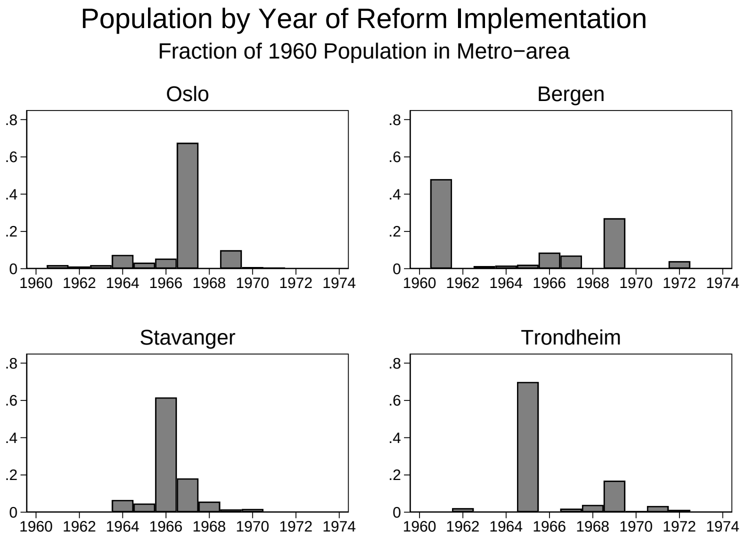
Note: Norwegian males born 1950–1980 observed 1967-2014 with experience 0-30 years and annual earnings above 1 SGA threshold (N=14,758,689). IQ scaled by 1 SD.

*p<0.1, **p<0.05, ***p<0.01.

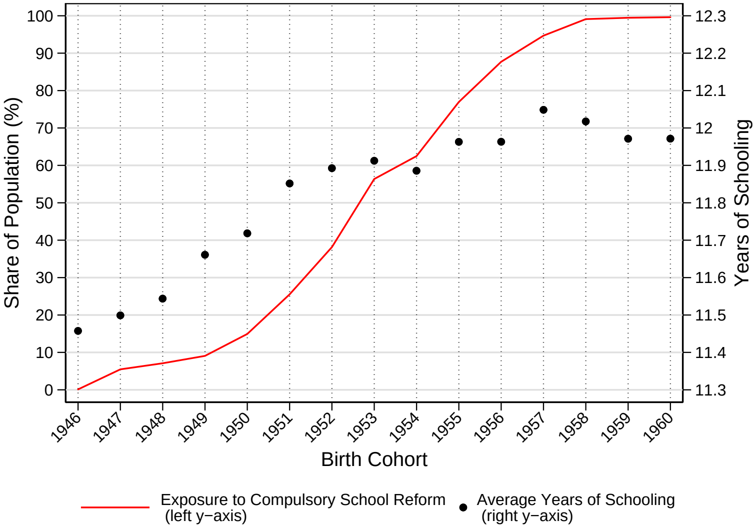
Instrument

- Increase in compulsory schooling from 7 to 9 years.
  - staged implementation between 1960 and 1975
  - across 732 municipalities (we have data for 672 of these)
- Municipalities are quite small and overlap with large metro areas.
  - Norway at the time had roughly 4 million inhabitants.
  - largest municipality is Oslo (ca. 500,000 inhabitants in metro area of 900,000)
- We believe it is unlikely that employers in the low skill labor market would keep track of compulsory schooling laws by cohort and municipality of residence when adolscent.

Implementation of Compulsory School Reform (1)



Implementation of Compulsory School Reform (2)



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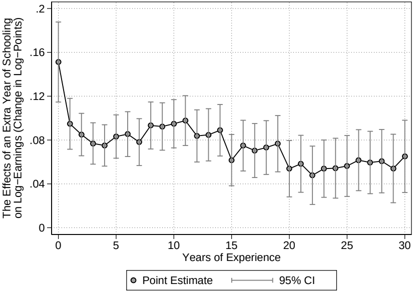
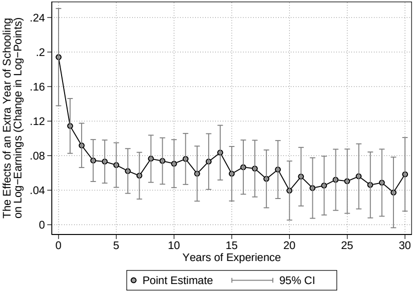
1. IV estimates of the returns to schooling by experience.
2. OLS estimates of returns to schooling and IQ-score by experience.
3. Estimates of Speed of Learning K_1 using
    - 3.1 OLS estimates
    - 3.2 IV estimates.
4. Internal rate of return for schooling.

IV Schooling Regression Coefficients by Experience

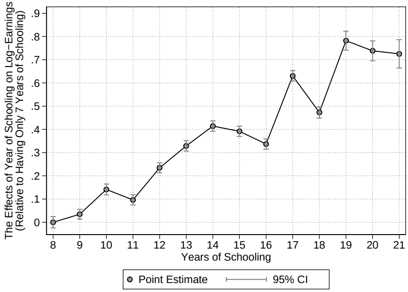


(a) Full Sample

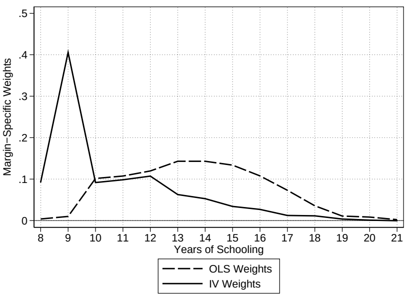


(b) Restricted Sample

Non-Linear Returns to Schooling and IV/OLS Weights



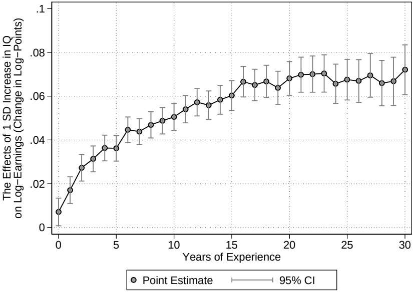
(c) Non-Linear Returns to Schooling



(d) OLS & IV Weights

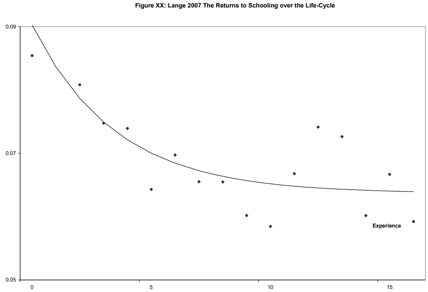
OLS Regression Coefficients on Schooling and IQ

(e) Coefficients on Schooling over t

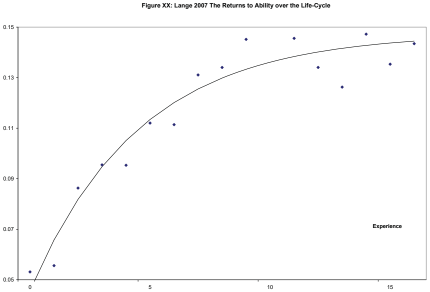


(f) Coefficients on IQ over t

Comparision Lange (2007)



(g) Coefficients on Schooling over t



(h) Coefficients on IQ over t

The Speed of Employer Learning

	IV-Weighted OLS estimates (1)	(2)	IV estimates (3)
	Years of Schooling	IQ Test Score	Years of Schooling
Speed of Learning K_1	0.377***	0.116***	0.464***
	(0.046)	(0.023)	(0.126)
Initial Value b_0	0.098***	0.008**	0.146***
	(0.005)	(0.004)	(0.013)
Limit Value b_∞	0.023***	0.087***	0.064***
	(0.002)	(0.003)	(0.004)

Note: The estimation sample consists of Norwegian males born 1950-1980 observed in earnings data over years 1967-2014 with years of experience between 0 and 30 years and annual earnings above 1 SGA threshold (N=14,758,689).

Implications for Private and Social Returns

- The estimated limit value b_∞ using the IV implies that the social returns to schooling are 6.4%.
- Internal rate of return of 8.1% for schooling investment over the life-cycle
  - assuming a career length of 40 years
  - and no financial costs of schooling.

Our Paper

1. **Clarify the role of assumptions on observability of instruments for interpreting IV estimates**
2. **Finds that there is statistical discimination using schooling in the Norwegian context**
3. **Provides evidence on employer learning**
   - across different methodologies
   - Speed of learning at 0.1-0.4
4. **Social returns of 6.4% compare to**
   4.1 Mincer returns of 6.8%.
   4.2 Internal rate of return of 8.1%.