Estimating the Return to Schooling: Progress on Some Persistent Econometric Problems

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Objective

- To measure the **causal effect of education** on labor market earnings by using institutional features of the supply side of educations system as an exogeneous determinants of schooling outcomes.

Key Finding

Author made a review of studies that have used compulsory schooling laws, differences in the accessibility of schools, and similar features as **IVs** for completed education, reveals that the resulting estimates of the return to schooling are typically as big or bigger than the corresponding **OLS'** estimates.

- We will give a few explanations or interpretations (if you will) of why this happens.

Background

- Resurgence of interest in the study of causal links between education and labor market success.
- Qualified vs Under-Qualified Workers.
- Revival in the determinants of economic growth.
- New focus on the role of human capital.
- Concerns about the relative costs and benefits of higher education for those who were not previously receiving it.

Introduction

Institutional features of the education system and supply-side variables.

- How are they used?
- Why?
- What is their impact today?

Aim

Card aims to present a present a survey and partial synthesis of the recent literature that has used "supply-side" features of the education system to help identify the causal effect of education. By doing this, he will try to reconcile various findings in the literature, and also provide a useful framework for generating new hypotheses and insights about the connection between education and earnings.

Structure

- Presentation of simple theoretical model of endogenous schooling.
- Use this model to to motivate an extended discussion of various econometric issues.
- Present a selective review of the recent literature on estimating the economic returns to education, drawing on studies of the U.S. and other developed economies, as well as a handful of studies of developing economies.

Framework

Card builds on Becker's (1967) model of endogenous schooling, since most conceptual issues underlying the interpretation of recent studies of the return to education can be illustrated in the framework presented by the latter.

- Individuals face a market opportunity locus that gives the level of earnings associated with alternative schooling choices.
- Thus, they reach an optimal schooling decision by balancing the benefits of higher schooling against the costs.

Strong Assumption

Traditionally, it is assumed that individuals seek to maximize the discounted present value of earnings, net of schooling costs

Model

- Assume that individuals have an infinite planning horizon that starts at the minimum school-leaving age ($t = 0$).
- They accumulate a flow of utility in period t that depends on:
  - consumption $c(t)$ at period t
  - Wether they are in school (and working part time) or out of school and working full time.
- **Utility while in school is**:

$$u(c(t)) - \phi(t)$$

- **Utility out of school is**:

$$u(c(t))$$

Note:

Note that $u(\cdot)$ is an increasing concave function and $\phi(t)$ is a convex function that represents relative disutility of school vs. work for the t-th year of schooling.

Finally,

- Individuals discount future utility flows at a subjective discount rate ρ, and make a once-for-all decision on when to leave school.

Therefore, one can define **lifecycle utility, conditional on schooling** S and a given consumption profile as

$$V(S, c(t)) = \int_0^S \Big[u(c(t) - \phi(t))\Big] e^{-\rho t} dt + \int_S^\infty u(c(t)) e^{-\rho t} dt$$

Intertemporal Budget Constraint

- Let $y(S,t)$ denote real earnings at age t of an individual who has completed S years of post-compulsory schooling (with $0 \leq S \leq t$).
- Assume that individuals who are in school at time t work part time and earn $p(t)$ and pay tuition costs of $T(t)$.
- Also, assume that individuals can borrow or lend freely at a **fixed** interest rate R.

Thus, we can define the **intertemporal budget constraint**:

$$\int_0^\infty c(t)e^{-Rt}dt = \int_0^S \Big[p(t) - T(t)\Big]e^{-Rt}dt + \int_S^\infty y(S,t)e^{-Rt}dt$$

Optimal Schooling choice and Optimal Consumption Path

Therefore, an individual's optimal schooling choice and optimal consumption path maximize

$$\begin{aligned}\Omega(S, c(t), \lambda) = V(S, c(t)) \\ - \lambda \Bigg[\int_0^\infty c(t) e^{-Rt} dt \; - \int_0^S \Big[p(t) - T(t) \Big] e^{-Rt} dt \\ - \int_S^\infty y(S, t) e^{-Rt} dt \Bigg]\end{aligned}$$

We can see that the FOC with respect to S yields:

$$\Omega_S(S, c(t), \lambda) = \lambda e^{-RS} [MB(S) - MC(S)]$$

Where,

- The Marginal Benefit of the S-th unit of schooling is defined by

$$MB(S) = \int_0^\infty \frac{\partial y(S, S+\tau)}{\partial S e^{-R\tau}} d\tau$$

- And, the Marginal Cost of S-th unit of schooling is given by

$$MC(S) = y(S,S) - p(S) + T(S) + \frac{1}{\lambda e^{-(\rho-R)S}} \phi(S)$$

What happens if $MC(S)$ rises faster than $MB(S)$?

We would need a necessary and sufficient condition for the optimal schooling choice S, i.e. $MC(S) = MB(S)$

Card solves this problem by assuming that log earnings are additively separable in education and years of post-schooling experience. Therefore, one can write the earnings function as $y(S,t) = f(S)h(t-S)$ (recall that $0 \leq S \leq t$), then

$$MB(S) = f'(S)\int_0^{\infty} h(\tau)e^{R\tau}d\tau \equiv f'(S)H(R)$$

where $H(R)$ is a decreasing function of the interest rate. Therefore, 2 conclusions arise:

1. If earnings are fixed after completion of schooling: $H(R) = \frac{1}{R}$
2. If earnings follow a *concave* lifecycle profile and taking g as a constant growth rate(equivalent to the lifecycle profile): $H(R) = \frac{1}{(R-g)}$

Therefore, under separability(check Minkowski's Theorem), the marginal costs and benefits of additional schooling are equated when

$$\frac{f'(S)}{f(S)} = \frac{1}{H(R)}\left[1 + \frac{(T(S)-p(S))}{f(S)} + \frac{1}{\lambda e^{-(\rho-R)S}}\frac{\phi(S)}{f(S)}\right]$$

General Case: $U(c(t)) = log[c(t)]$

The FOC's for an optimal consumption profile, together with the lifecycle budget constraint, imply that

$$\frac{1}{\lambda} = \rho\left\{e^{-RS}f(S)H(R) + \int_0^S \Big[p(t) - T(t)\Big]e^{-Rt}dt \equiv \rho W(S)\right\}$$

where $W(S)$ is the value of lifecycle wealth associated with the schooling choice S. If $T(S) \approx p(S)$ then

$$\frac{f'(S)}{f(S)} = R - g + \rho e^{-\rho S}\phi(S) \equiv d(S) \tag{1}$$

Observations

The interest rate must be adjusted to reflect lifecycle earnings growth and the marginal cost has to account for the relative disutility of attending the Sth year of schooling.

Heterogeinity in the Optimal Schooling Choice

Individual heterogeinity can arise from 2 sources:

1. differences in the economic benefits of schooling,
2. differences in the marginal costs of schooling.

Then we would have

$$\frac{f'(S)}{f(S)} = b_i - k_1 S, \quad k_1 > 0 \tag{2}$$

$$d(S) = r_i + k_2 S, \quad k_2 > 0 \tag{3}$$

where $b_i \sim F(\bar{b}, \sigma_b^2)$, $r_i \sim F(\bar{r}, \sigma_r^2)$. Equating (2) with (3) and solving for S will yield,

$$S_i = (b_i - r_i)/k, \quad k = (k_1 + k_2) > 0 \tag{4}$$

At the equilibrium level of schooling described by equation (4) individual i's marginal return to schooling is

$$\beta_i \equiv b_i - k_1 S = b_i(1 - \frac{k_1}{k}) + r_i \frac{k_1}{k}$$

The average marginal return to education is therefore,

$$\bar{\beta} = \mathbb{E}[\beta_i] = \mathbb{E}[b_i - k_1 S] = \bar{b} + k_1 \bar{S}$$

Interpretation of equation (4)

Card interprets (4) as partial equilibrium description of the relative education choices of a cohort, given the institutional environment and economic conditions that prevailed during their late teens and early twenties.

Econometric Issues Raised By Endogenous Schooling: OLS Estimates of the Return to Schooling

Note that equation (2) implies a model for log earnings of the form

$$log\ \ y_i = a_0 + \bar{b}S_i - \frac{1}{2}k_1 S_i^2 + a_i + (b_i - \bar{b})S_i, \tag{5}$$

where $a_i \equiv \alpha_i - a_0$ has mean 0. Together with some algebraic manipulation andconsidering the linear projectos of the underlying random variables $a_i, \quad b_i$ and r_i, one can rewrite expression (5) as

$$log\ \ y_i = K + (\bar{b} + \lambda_0 - \psi_0 \bar{S})S_i + (\psi_0 - \frac{1}{2}k_1)S_i^2 + u_i + v_i S_i, \tag{6}$$

Equations (4) and (6) together describe a two-equation system for schooling and earnings in terms of the underlying random variables a_i, b_i, and r_i. Ignoring other covariates (or assuming these have already been conditioned out) it is straightforward to derive the implications of this model for conventional OLS estimates of the return to schooling.

Moreover, under the assumption that the third central moment of the joint distribution of b_i and r_i we have that $\mathbb{E}[(S_i - \bar{S})^3] = 0$. Then, the probability limit of the OLS regression coefficient b_{OLS} from a regression of equation (6) is

$$plim \quad b_{OLS} = \bar{\beta} + \lambda_0 + \psi_0 \bar{S} \tag{7}$$

If there is no heterogeinity in MB(S) and that the log earnings are linear in schooling (i.e. $k_1 = 0$). Then (7) implies

$$plim \quad b_{OLS} - \bar{\beta} = \lambda_0$$

- Generally, people with a higher return to education have an incentive to acquire more schooling, a cross-sectional regression of earnings on schooling is likely to yield an upward-biased estimate of the average marginal return to schooling.
- With a larger bias the more important are the comparative advantage incentives that lead individuals with higher returns to schooling to acquire mor schooling.
- Problems arising from the measurment of schooling (Griliches 1977) Downward bias in the OLS estimate of the effect of schooling on earnings vs. Upward bias of the effect of ability on earnings.

IV Estimates of the Return to Schooling

Trends

Recently, much attention has focused on supply-side sources of variation in schooling, attributable to such features as the minimum school-leaving age, tuition costs, or the geographic proximity of schools.

Suppose that the marginal cost component r_i is *linearly independent* realted to a **set of observable variables** Z_i: $r_i = Z_i\pi_1 + \eta_i$, where η_i takes into account other unobserved taste and cost factors; also, η_i is uncorrelated with Z_i.

The Optimal Schooling Choice is

$$S_i = \frac{(b_i - r_i)}{k} = \frac{\bar{b}}{k} - \frac{Z_i\pi_1}{k} + \frac{(b_i - \bar{b} - \eta_i)}{k} = Z_i\pi + \xi_i$$

(4')

- If a_i is the only individual-specific component of ability, then equations (4') and (5) constitute a standard simultaneous equations system.
- It is sufficient to suppose $\mathbb{E}[a_i Z_i] = 0$, to ensure that an IV estimator based on Z_i will yield a consistent estimate of the average return to schooling $\bar{b}$.
- So, we have that Z_i is independent from individual abilities and the reduced form of schooling residual ξ_i

Then,

$$
\begin{aligned}
\mathbb{E}[log \quad y_i \quad | \quad Z_i] &= \mathbb{E}\left[a_0 + \bar{b}S_i - \frac{1}{2}k_1 S_i^2 + a_i + (b_i - \bar{b})S_i \mid Z_i\right] \\
&= a_0 + \bar{b}Z_i - \frac{1}{2}k_1(Z_i\pi)^2 - \frac{1}{2}k_1\mathbb{E}[\xi_i^2 \mid Z_i] \\
&+ \mathbb{E}[(b_i - \bar{b})\xi_i \mid Z_i]
\end{aligned}
$$

- Thus, the average marginal return to schooling can be consistently estimated by IV. Why?

Treatments

Note:

Unfortunately, the assumptions proposed previously and weaker ones proposed by Woolridge (1997), are likely to be violated when Z_i is a variable representing exposure to institutional structures on the supply-side of the education system.

Assume that the joint distribution of abilities and tastes $(a_i . b_i, r_i)$ is the same for individuals who attended the reformed schools (i.e. Z_i=1) and those who did not (i.e. Z_i=0); however, for reformed schools the optimal choice of schooling is given by

$$S_i = \frac{(b_i - \theta r_i)}{k}; \quad \theta < 1 \tag{4''}$$

Take $r_i = \bar{r} + \eta_i$; then,

- Unreformed Schools: $S_i^u = \pi_0 + \xi_{i0}$,
- Reformed Schools: $S_i^R = \pi_0 + \pi_1 + \eta_{i1}$,
- Reduced form schooling equation is therefore

$$S_i = \pi_0 + Z_i \pi_1 + \xi_i \quad ; \quad \xi_i = (1 - Z_i)\xi_{i0} + Z_i \xi_{i1}$$

Note:

Since the schooling reform lowers the effect of cost differences in the optimal schooling decision, $Var[\xi_i \mid Z_1] \leq Var[\xi_i \mid Z_0] = 0$.

Some evidence that changes in the institutional structure of the education system affect the mapping between ability and schooling outcomes:

TABLE I

RELATIONSHIP BETWEEN IQ AND SCHOOLING

	Pooled Sample (1)	(2)	Near College (3)	(4)	Not Near College (5)	(6)
Coefficient of IQ	0.075	0.068	0.081	0.072	0.059	0.058
	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)	(0.006)
Other Controls	No	Yes	No	Yes	No	Yes
R-squared	0.260	0.348	0.249	0.375	0.175	0.299
Number of Observations	2,061	2,061	1,460	1,460	601	601

Note: Table reports coefficient of IQ in a linear regression model for completed education in 1976. Models in odd columns include no other controls. Models in even columns include both parents' education, age and age-squared, indicators for race, family structure at age 14, and region in 1966. Near College subgroup are those whose county of residence in 1966 had a local 4-year college (public or private). Sample includes men in the NLS Young Men sample who were interviewed in 1976 and who have valid education data for their parents and an IQ score obtained from their school records.

Conclusion

Assuming the presence of nearby college is uncorrelated with ability, **college proximity is a potential IV for schooling**.

Alternatives to IV

- Control Function Approach(Garen, 1984).

Basic Idea

Make some assumptions about the nature of the covariances between the unobserved ability components a_i and b_i and the observable variables S_i and Z_i, and include additional terms in the earnings model that capture these relationships.

- Assume mean-independence between unobserved ability and taste components and Z; also, he conditional expectations of the unobserved ability components a_i and b_i are linear in the schooling residual:

$$\mathbb{E}[(b_i - \bar{b}) \mid S_i, Z_i] = \psi_0 \xi_i, \tag{8a}$$

$$\mathbb{E}[a_i \mid S_i, Z_i] = \lambda_0 \xi_i. \tag{8b}$$

Together with eqaution (5), this equations imply that

$$\mathbb{E}[log\ \ y_i \mid Z_i] = a_0 + \bar{b}S_i - \frac{1}{2}k_1 S_i^2 + \lambda_0 \xi_i + \psi_0 \xi_i S_i$$

This equation can be estimated by a two-step procedure in which the estimated residual from the reduced form schooling equation is substituted for ξ_i, and is substituted for ξ_i, $\hat{\xi}_i S_i$ is substituted for $\xi_i S_i$.

- Assumption (8a) IS PROBLEMATIC! Why?
  - $Cov[b_i, \xi_1 \mid Z_i]$ and $Var[\xi_i \mid Z_i]$ potentially vary with Z_i
- A simple extension of the control function approach may be appropiate if Z_i is an indicator variable. Remember the college proximity idea?
- Taking this into account, and with some algebraic manipulation of equations (8a), (8b) then

$$\mathbb{E}[log\ \ y_i \mid Z_i] = a_0 + \bar{b}S_i - \frac{1}{2}k_1 S_i^2 + \lambda_{00}\xi_i + (\lambda_{01} - \lambda_{00})Z_i\xi_i + \psi_{00}\xi_i S_i + (\psi_{01} - \psi_{00})Z_i S_i \xi_i$$

A more radical approach

Maximum likelihood estimation of a structural model of earnings and schooling, based on a complete specification of the unobservable components in the earnings function and the utility function.

Edge

An advantage of this approach is that the earnings function can be made quite general; for example, by allowing the returns to different years of schooling to vary in a flexible manner with individual ability.

What Does a Conventional IV Estimate?

Suppose that:

- A given individual would have schooling level S_i^c and earning y_i^c if he or she attended regular school system.
- If he or she attended a reformed school, then the individual would have a schooling outcome of $S_i^c + \Delta S_i$

Let $\beta \equiv$ individual i's marginal return to schooling. Then the effect of schooling reform on earnings for individual i is

$$\Delta log \ y_i = \beta_i \cdot \Delta S_i$$

Implying,

$$(*) \quad plim \ b_{IV} = \frac{Cov[log \ y_i, Z_i]}{Cov[S_i, Z_i]} = \frac{\mathbb{E}[log \ y_i \mid Z_i = 1] - \mathbb{E}[log \ y_i \mid Z_i = 0]}{\mathbb{E}[S_i \mid Z_i = 1] - \mathbb{E}[S_i \mid Z_i = 0]}$$
$$= \frac{\mathbb{E}[\beta_i \cdot \Delta S_i]}{\mathbb{E}[\Delta S_i]}$$

Note:

If marginal return to schooling and treatment of schooling (ΔS_i), then the IV estimator is a consistent estimate of the avg. marginal return to eduction $\bar{\beta} = \mathbb{E}[\beta_i]$

- An IV procedure based on a school reform that leads to bigger changes in the education choices of people with relatively high marginal returns to education will tend to produce an over-estimate of the average marginal return to education.
- Important to reconsider that the effects of a supply-side change that causes a porportional reduction in MC(S). This induced change is represented by

$$\Delta S_i = r_i \frac{1-\theta}{k} = \bar{r}\frac{(1-\theta)}{k} + \eta_i \frac{(1-\theta)}{k} > 0$$

Thus, the monoticity assumption required for LATE is satisfied.

Then, individual i's marginal return to schooling (in the absence intervention) is

$$\beta_i = \bar{\beta} + (b_i - \bar{b})(\frac{1-k_1}{k}) + \eta_i \frac{k_1}{k}$$

Susbtituting in equation $(*)$,

$$plim\ b_{IV} = \bar{\beta} + \left[\sigma_\eta^2 \frac{k_1}{k} + \frac{\sigma_{b\eta}}{\bar{r}}(\frac{1-k_1}{k})\right]$$

Two features are worth noticing:

1. The probability limit of the IV estimator is unaffected by classical measurement error in schooling.
2. The validity of a particular IV estimator depends crucially on the assumption that the instruments are uncorrelated with other latent characteristics of individuals that may affect their earnings.

IV Estimates of the Return to Schooling

TABLE II

OLS AND IV ESTIMATES OF THE RETURN TO EDUCATION WITH INSTRUMENTS BASED ON FEATURES OF THE SCHOOL SYSTEM

Author	Sample and Instrument		Schooling Coefficients OLS	IV
1. Angrist and Krueger (1991)	1970 and 1980 Census Data, Men. Instruments are quarter of birth interacted with year of birth. Controls include quadratic in age and indicators for race, marital status, urban residence.	1920–29 cohort in 1970	0.070 (0.000)	0.101 (0.033)
		1930–39 cohort in 1980	0.063 (0.000)	0.060 (0.030)
		1940–49 cohort in 1980	0.052 (0.000)	0.078 (0.030)
2. Staiger and Stock (1997)	1980 Census, Men. Instruments are quarter of birth interacted with state and year of birth. Controls are same as in Angrist and Krueger, plus indicators for state of birth. LIML estimates.	1930–39 cohort in 1980	0.063 (0.000)	0.098 (0.015)
		1940–49 cohort in 1980	0.052 (0.000)	0.088 (0.018)
3. Kane and Rouse (1993)	NLS Class of 1972, Women. Instruments are tuition at 2 and 4-year state colleges and distance to nearest college. Controls include race, part-time status, experience. Note: Schooling measured in units of college credit equivalents.	Models without test score or parental education	0.080 (0.005)	0.091 (0.033)
		Models with test scores and parental education	0.063 (0.005)	0.094 (0.042)
4. Card (1995b)	NLS Young Men (1966 Cohort) Instrument is an indicator for a nearby 4-year college in 1966, or the interaction of this with parental education. Controls include race, experience (treated as endogenous), region, and parental education	Models that use college proximity as instrument (1976 earnings)	0.073 (0.004)	0.132 (0.049)
		Models that use college proximity × family background as instrument	—	0.097 (0.048)

5. Conneely and Uusitalo (1997)	Finnish men who served in the army in 1982, and were working full time in civilian jobs in 1994. Administrative earnings and education data. Instrument is living in university town in 1980. Controls include quadratic in experience and parental education and earnings.	Models that exclude parental education and earnings	0.085 (0.001)	0.110 (0.024)
		Models that include parental education and earnings	0.083 (0.001)	0.098 (0.035)
6. Harmon and Walker (1995)	British Family Expenditure Survey 1978–86 (men). Instruments are indicators for changes in the minimum school leaving age in 1947 and 1973. Controls include quadratic in age, survey year, and region.		0.061 (0.001)	0.153 (0.015)
7. Ichino and Winter-Ebmer (1998)	Austria: 1983 Census, men born before 1946. Germany: 1986 GSOEP for adult men. Instrument is indicator for 1930–35 cohort. (Second German IV also uses dummy for father's veteran status). Controls include age, unemployment rate at age 14, and father's education (Germany only). Education measure is dummy for high school or more.	Austrian Men	0.518 (0.015)	0.947 (0.343)
		German Men	0.289 (0.031)	0.590/0.708 (0.844) (0.279)
8. Lemieux and Card (1998)	Canadian Census, 1971 and 1981: French-speaking men in Quebec and English-speaking in Ontario. Instrument is dummy for Ontario men age 19–22 in 1946. Controls include full set of experience dummies and Quebec-specific cubic experience profile.	1971 Census:	0.070 (0.002)	0.164 (0.053)
		1981 Census:	0.062 (0.001)	0.076 (0.022)
9. Meghir and Palme (1999)	Swedish Level of Living Survey (SLLS) data for men born 1945–55, with earnings in 1991, and Individual Statistics (IS) sample of men born in 1948 and 1953, with earnings in 1993. Instrument is dummy for attending "reformed" school system at age 13. Other controls include cohort, father's education, and county dummies. Models for IS data also include test scores at age 13.	SLLS Data (Years of education)	0.028 (0.007)	0.036 (0.021)
		IS Data (Dummy for 1–2 years of college relative to minimum schooling)	0.222 (0.020)	0.245 (0.082)

TABLE II—*Continued*

Author	Sample and Instrument		Schooling Coefficients OLS	IV
10. Maluccio (1997)	Bicol Multipurpose Survey (rural Philippines): male and female wage earners age 20–44 in 1994, whose families were interviewed in 1978. Instruments are distance to nearest high school and indicator for local private high school. Controls include quadratic in age and indicators for gender and residence in a rural community.	Models that do not control for selection of employment status or location	0.073 (0.011)	0.145 (0.041)
		Models with selection correction for location and employment status	0.063 (0.006)	0.113 (0.033)
11. Duflo (1999)	1995 Intercensal Survey of Indonesia: men born 1950–72. Instruments are interactions of birth year and targeted level of school building activity in region of birth. Other controls are dummies for year and region of birth and interactions of year of birth and child population in region of birth. Second IV adds controls for year of birth interacted with regional enrollment rate and presence of water and sanitation programs in region.	Model for hourly wage	0.078 (0.001)	0.064/0.091 (0.025) (0.023)
		Model for monthly wage with imputation for self-employed.	0.057 (0.003)	0.064/0.049 (0.017) (0.013)

Notes: See text for sources and more information on individual studies.

Conclusions

- We have attempted to measure the causal effect of education on labor market earnings by using institutional features on the supply side of the education system as exogenous determinants of schooling outcomes.
- Card believes it is helpful to place the returns to education literature in a standard "supply and demand" framework, which leads to a somewhat richer econometric model for schooling and earnings than is usually adopted in the applied literature.

NOTE:

Different individuals finish their schooling at a point where the marginal return to the last unit of education may be either above or below the average marginal return in the population as a whole.

Conclusions

- IV estimation will typically recover a weighted avg. of returns to education for people whose choices were affected by the instrument, rather than the marginal return to education in the population.
- IV estimates of the return to schooling that are at least as big and sometimes substantially bigger than the corresponding OLS estimates.
- In many cases the IV estimates are relatively imprecise, and none of the empirical strategies is based on true randomization.
    - Thus, no individual study is likely to be decisive in the debate over the magnitude of ability biases in OLS estimates of the return to schooling.
- Seems that Griliches' (1977) assessment was spot on.

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