# Education Production Function

## Theory

Dewy, Husted & Kenny, "The Ineffectiveness of School Inputs: A Product of Misspecification?" *Economics of Education Review*, 2000.

**Why** - need to understand the production of knowledge in order to evaluate policy debates surrounding education (e.g., does competition make schools more efficient?)

**Parent's Utility** - based on education vs. everything else: $U(L,C)$ (1)

$L =$ amount child learns

$C =$ other consumption

**Education** - production function: $L = f(S, t_L, E)$ (2)

$S =$ quality of the school system

$t_L =$ parents' quantity of time teaching child

$E =$ parents' educational attainment (proxy for quality of time)

**Problem** - learning occurs over many years, but this model doesn't incorporated learning over time; in a perfect world, we'd have data on inputs over time

**Other Consumption** - production function: $C = g(X, t_c, E)$ (3)

$X =$ amount of goods purchased

$t_C =$ time devoted to other consumption

This is based on economics of the household framework by Becker (1960s)

**Budget Constraint -**

**Time Budget Constraint** - $T = t_L + t_C + t_W$ (4)

$t_W =$ time spent working

$T =$ available time

**Goods Budget Constraint** - $P_S \cdot S + X = w \cdot t_W$ (5)

$P_S =$ price of school quality

$w =$ hourly wage rate

Sub (4) into (5): $P_S \cdot S + X = w \cdot (T - t_L - t_C)$

Rearrange terms: $(\underbrace{P_S S}_{\text{Purchased school quality}} + \underbrace{wt_L}_{\text{Value of time spent with kid}}) + (\underbrace{X}_{\text{Other goods purchased}} + \underbrace{wt_C}_{\text{Value of time spent on consumption}}) = \underbrace{wT}_{\text{Potential income}}$ (6)

**Parent's Problem** - maximize utility subject to production functions and budget constraint

| | |
|---|---|
| $\max U(L,C)$ | utility (1) |
| s.t. $L = f(S, t_L, E)$ | education production function (2) |
| $C = g(X, t_c, E)$ | consumption production function (3) |
| $(P_S S + wt_L) + (X + wt_C) = wT$ | budget constraint (6) |

**Solution** - determines demand functions for the two outputs ($L, C$) and their inputs:

Outputs: $L = D_1(T, w, P_S, E)$, $C = D_2(T, w, P_S, E)$

Inputs: $S = D_3(T, w, P_S, E)$, $X = D_4(T, w, P_S, E)$, $t_L = D_5(T, w, P_S, E)$, $t_C = D_6(T, w, P_S, E)$

**Linear Assumption** - is we linearize education production function:

$$L = b_0 + b_1 S + b_2 t_L + b_3 E \quad (7)$$

**Problem** - no data set has all these variables; data sets with information on school quality ($S$) are usually missing information on parental time helping kids ($t_L$)

**Options** - four ways of dealing with lack of data on $t_L$

(a) **Time Working** - $t_W$ is negatively correlated with $t_L$ (i.e., if parents' work more, they probably spend less time teaching their kids)

(b) **Hourly Wage** - common practice in literature: $L = b_0 + b_1 S + b_3 E + b_4 w$ (8)

Either use hourly wage ($w$) or income

**Problem** -

- $w$ is poor proxy for $t_L$ ... conflicting income and substitution effects
  Income - income$\uparrow \Rightarrow$ demand for leisure$\uparrow$
  Substitution - income$\uparrow \Rightarrow$ opportunity cost for leisure$\uparrow \Rightarrow$ demand for leisure $\downarrow$
- mixing production function input ($S$) with demand function input ($w$); these variables are highly correlation since $S$ is a function of $w$ (rich communities demand high quality school systems); introduces multicollinearity

(c) **Ignore Time with Kids** - $L = b_0 + b_1 S + b_3 E$ (9)

Effect of $t_L$ will be captured by error term, but Rosen & Flyer (*Journal of Labor Economics*, 1997) find positive correlation between female labor force participation and school quality (i.e., women who work substitute $S$ for $t_L$); R&F found positive correlation between work time and $S$, which implies negative correlation between $t_L$ and $S$ so there will be a negative bias on the coefficient of $S$ on (9)... less likely to see importance of school quality on learning

(d) **Instrumental Variable Approach** - estimate demand for $S = D_3(T, w, P_S, E)$ (demand function from bottom of p.1); use predicted values of $S$ in production function

$$L = b_0 + b_1 \hat{S} + b_3 E \quad (10)$$

Now coefficient on $\hat{S}$ is unbiased

**Problem** - good IVs are hard to find

## Evidence

Dewy, Husted & Kenny - summarize literature: 127 regressions explaining test scores from 46 papers; allow different samples (e.g., elementary and high school), and separate dependent variables (e.g., reading and math scores), but only use "best" regression for each case

**Bad Models** - 92 of 127 regressions were bad, because...

had no measure of parental time ($t_L$ or $E$) [14], or

included income or wage ($w$) [85] (i.e., used demand variable in production function)

**Inputs** - all variables are (should be) inputs to production function so they should have positive coefficients

**Meta-Analysis** - combine 414 coefficients from all 127 regressions:

| | **Good Studies** | **Bad Studies** |
|---|---|---|
| **Positive Coefficients** | 75.2% | 66.7% |
| **+ & Sig @ 5.0% (1 tail)** | 41.9% | 35.0% |
| **+ & Sig @ 2.5% (1 tail)** | 38.1% | 27.5% |

**Good vs. Bad** - good studies are more likely to have positive and significant coefficients
**Overall** - overall measure of significance obtained using inverse chi-square test (also known as Fisher or Pearson $P_\lambda$); by combining all coefficients from all papers (good and bad) the following inputs all have significantly positive effects: teacher education, teacher experience, teacher salary, other teacher characteristics, teachers per student, expenditures per student
**"School Matters"** - school inputs matter for test scores

## Impact of Teachers

**Traditional Approach** - earnings function in labor economics:
$w = f$(compensating wage differential, skill measures, union)
**Compensating Wage Differential** - firms in different locations compete to attract workers; wages adjust so that some workers are indifferent between locations; adjust for...
**Cost of Living** - 10% higher cost of living, expect 10% higher wages
**Climate** - less desirable climate (too hot or too cold) requires higher wages
**Risk** - increased chance of death or injury requires higher wages
**Skill Measures** - firms willing to pay skilled workers more; measure skill by...
**Years of Education** - skills learned in school
**Years of Experience** - skills learned on the job
**Union** - union interferes with labor market and drives wage above market wage; significant for education because results in 95% of schools using salary scale where wages depend *only* on years education and experience
**No Merit Pay** - no incentive to be a better teacher
**Applying to Schools** -
(a) **Earnings Function** -
**Years of Education** - used to capture skills teachers learned in school
From "good" studies, DHK found 25% of teacher education coefficients were positive and significant
Problem - little variation in education among teachers; mostly due to large number of education courses taken ("Total time spent in school is usually correlated to taking a bunch of useless education courses")
**Years Teaching** - used to capture skills teachers learned on the job
From "good" studies, DHK found 52% of teacher experience coefficients were positive and significant
Problem - recent evidence suggests most of the gain for teachers comes in the first two years, then it benefit of experience levels off
(b) **Teacher Salary** - could pick up education and experience; assumes higher salary can attract better teachers
Problem - must control for compensating wage differentials and union premium
**Teacher Test Scores** - expect teacher with a high score in math will be a better math teacher
Strauss & Sawyer (*Economics of Education Review*, 1986) - used 145 NC districts; found higher average NTE test scores for teachers implied higher student test scores
**Problem** - only a few data sets have teacher test scores
**Selectivity of College Attended** - expect teacher from more selective (i.e., "better") college will be a better teacher
Ehrenberg & Brewer (*Economics of Education Review*, 1994) - used calculated average selectivity (based on *Barrons*) of college attended by high school's teachers; found student test scores rose as selectivity increased
**Problem** - want to match score to when the teacher attended the college because scores change over time

**Alternative** - use average SAT score for the college instead of the selectivity (JC)

**Majoring in Field** - expect a math major to be a better math teacher

Goldhaber & Brewer (*JHR*, Summer 1997) - found math scores are higher if the teacher has a BA or MA in math

"Teachers are wasting time taking all these dumb education courses"

Pay schedules ignore the opportunity cost of subject areas (can get better paying job outside of teaching)

**Teacher Fixed Effects** - use dummy variable for each teacher to capture teacher effectiveness; studies show there is variation in teacher quality

Hanushek (*Journal of Political Economy*, Feb 1992) - used fixed effects; R-squared increased by 1/3

"1 std dev below mean to 1 std dev above mean $\Rightarrow$ student test scores up 1 std dev (1 grade equiv)" (I'm not sure what that means)

Goldhaber & Brewer (JHR, Summer 1997) - using fixed effects raised R-squared from .77 to .89

**Bonus** - estimated teacher fixed effects can be basis for raises

**Discussion Article**

Southwick & Gill, "Unified Salary Schedule and Student SAT Scores: Adverse Effects of Adverse Selection in the Market for Secondary School Teachers," *Economics of Education Review*, 1997.

**Unified Salary Schedule** - pay is based solely on the years of schooling and teaching experience

**Background** -

Salary Changes from 1985 to 1991: (143)

**Teachers** - ↑5.5%/year

**Math Oriented** - ↑>6%/yaer (accounting, computer systems analysts, engineers)

**Verbally Oriented** - ↑4.5%/year (advertising, copyreaders, editors)

"Some writers argue that there will not be a shortfall in the *number* of teachers; the courses will be taught, although by less well-qualified teachers." (143)

**Model** -

Quality (capability) of teachers is function of teacher salary and the salary in alternative employment: $Q_i = f_i(S_T, S_i) \quad (i = M, E)$

$\frac{\partial Q_i}{\partial S_T} > 0$ (more teacher pay attracts better teachers)

$\frac{\partial Q_i}{\partial S_i} < 0$ (more pay for alternatives [higher opportunity cost] lowers teacher quality)

Student performance is function of teacher quality: $SAT_i = g_i(Q_i, \text{other inputs})$

**SAT Scores** - "While this is an imperfect measure, it is nationally uniform, and is used to monitor the performance of the secondary school system by policy makers and researchers." (144)

**Two Models** - assume $Q_i$ and $SAT_i$ are linear in logs:

(1) $\ln(SAT_i) = a_0 + a_1 \ln(S_T) + a_2 \ln(S_i)$ ... expect $a_1 > 0$ and $a_2 < 0$

(2) $\ln(SAT_i) = c_0 + c_1 \ln(S_i / S_T)$ ... expect $c_1 < 0$

(2) <u>assumes</u>: $a_2 = b_2$ (alternative pay affects teachers equally), $a_1 = b_1 = -a_2$ (it's only the differential salaries [opportunity cost] that is important)

**Difference** - theory really only talks about the relative effect so (2) gives just as much information to confirm the theory as (1), but (2) is better (according to Kenny) because it removes the compensating wage differentials (the authors for some reason like (1) better, but didn't say why)

**Hypotheses Tested** - in English: looking to see if higher wage differential ⇒ lower quality

Teacher salary ↑ ⇒ SAT scores↑

Alternative salary ↑ ⇒ SAT scores↓

**Data** - Annual SAT average values from each state and DC from 1985 to 1991 from *Digest of Education Statistics*

357 observations, but cut to 256 because some states use ACT instead of SAT

**Alternative Wages** - use *Occupational Outlook Quarterly* to get "average wages in industries that make heavy usage of mathematical or verbal skills at an education-level equivalent to that of a secondary school teacher, a bachelor's degree or higher" (145);

Specifics:

- Look at occupations that generally require four year degree
- Choose industries where these occupations are large proportion of total employees

Industries Chosen:

| Math Oriented | | | Verbal Oriented | | |
|---|---|---|---|---|---|
| **SIC Code** | **Industry Name** | **Employees (1000s)** | **SIC Code** | **Industry Name** | **Employees (1000s)** |
| 8911 | Engineering & architecture | 742 | 7311 | Advertising agencies | 168 |
| 8721 | Accounting, auditing & bookkeeping | 537 | 7361 | Employment agencies | 265 |
| | | | 8641 | Civic & social associations | 427 |
| 7371 | Computer programming | 264 | 8111 | Legal services | 920 |
| | | | 4832 | Radio broadcasting | 121 |

**Why Industry** - "the data available was for the average state wage for the industry, not occupation" (145)

**Problem** - good technique for available data, but very judgmental; authors didn't cite cutoff for "large proportion"

**% Taking SAT** - expect better students to take the SAT so % taking ↑ ⇒ Scores ↓

**Other** - "to account for the possibility that there are systematic changes over time, we include dummy variables for each year. We also use the state per capita income as an explanatory variable, possibly proxying other resource at the disposal of the school system." (146); more variables:

Salary... measures teacher quality

Student/Teacher Ratio... measures teacher quantity

% Revenue Raised Locally... ??

Staff/Teacher Ratio... ?? (doesn't distinguish between support and administration)

Per Capita Income... BAD

**Problems** -

**State Level** - education is usually at a more local level; should use county or district level

**Per Capita Income** - DHK paper talked about how this is not good to include for education production function; could use average educational attainment in the state instead

**Leave vs. Join** - it's easier to leave teaching than to become a teacher (because of "stupid educational requirements")

**Results** -

"Higher alternative (nonteaching) wages for teachers of any subject (mathematics or verbally oriented) result in the relatively able people leaving or staying away form teaching" (143)

"There is a strong negative effect of the opportunity cost of teaching in a specialty on the performance of students in that area, evidenced by student scores in the SAT" (143)

**Tiny Effects** - 10%↑ in math salaries ⇒ 0.4%↓ in math SAT score... "with an average SAT score of 498, that decrease would be about two to three points" (**NOTE:** increments of SAT scores is 10 points)... Josh: this is not economically significant

**Other Research** - JC suggested looking at cost of unified pay (i.e., policy implications); what's the cost to improve the math scores vs. the verbal scores

Why finance PhDs get paid more the economics PhDs: "It's a compensating wage differential for spending your life reading boring questions."