Nonparametric Estimation of the Cost of Adequacy in Education:
The Case of Dutch Schools

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Introduction I

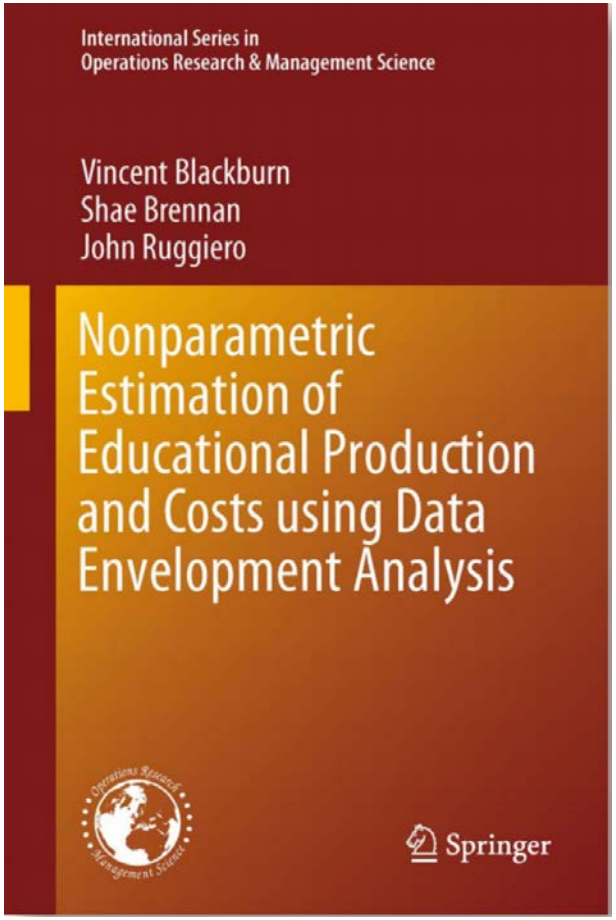
- Equity: Differences in Expenditures per pupil
- Public Finance Models of local public goods: Bradford, Malt and Oates (1960s)
- Output determined by inputs (labor, capital, etc.)
- Outcomes determined not only by output (lessons) but also by exogenous socioeconomic factors.
- Coleman Report: Educational Outcomes in the U.S. primarily determined by socioeconomic factors.
- Hanushek and economics of education: modeling education production using outcomes and socioeconomic factors.

Introduction II

- Previous focus in education finance literature was on equity: Differences in expenditures implies differences in outcomes.
- But expenditure differentials are caused by more than outcome differences. Differences can also be attributed to resource price differentials and the socioeconomic environment.
- Ruggiero, Blanchard and Miner (2002, EJOR) – large percentage of perceived inequity was due to inefficiency.
- Movement in the last 20 years has been away from equity standards towards accountability and adequacy.
- Adequacy: min. costs necessary to meet an absolute (pre-defined) standard of performance.

Introduction III

- Forsund (1972) invented “DEA” but called it something else.
- De Witte and Kortelainen (2024) introduced the conditional DEA model to control for environmental differences. See also Ruggiero (1996, 1998)
- Ruggiero (2007) used the conditional model (DWK) applied to costs to provide a measure of costs of adequacy.
- Haelermans and Ruggiero (2013) extended the 1996 model to measure technical and allocative efficiency with an application to Dutch schools.
- Brennan, Haelermans and Ruggiero (2014) extended the conditional model to measure public sector productivity and applied the model to analyze Dutch schools.


International Series in
Operations Research & Management Science
Vincent Blackburn
Shae Brennan
John Ruggiero
Nonparametric Estimation of Educational Production and Costs using Data Envelopment Analysis
Springer

Description of Technology

Production possibilty set condition on level of environment

$$T(z) = \{(Y, X, z) : \sum_{j=1}^{n} \lambda_j y_{kj} \geq y_k, k = 1, \ldots, s;$$

$$\sum_{j=1}^{n} \lambda_j x_{lj} \leq x_l, l = 1, \ldots, m;$$

$$\sum_{j=1}^{n} \lambda_j = 1;$$

$$\lambda_j = 0 \text{ if } z_j > z, \ j = 1, \ldots, n;$$

$$\lambda_j \geq 0, \ j = 1, \ldots, n\}.$$

Measuring Technical Efficiency

$$TE_i = Min\ \theta$$

$$s.t.$$

$$\sum_{j=1}^{n} \lambda_j y_{kj} \geq y_{ki},\ k = 1,\ldots,s;$$

$$\sum_{j=1}^{n} \lambda_j x_{lj} \leq \theta x_l,\ l = 1,\ldots,m;$$

$$\sum_{j=1}^{n} \lambda_j = 1;$$

$$\lambda_j = 0 \text{ if } z_j > z_i,\ j = 1,\ldots,n;$$

$$\lambda_j \geq 0,\ j = 1,\ldots,n.$$

Measuring Cost Efficiency

$$C_i^* = Min \sum_{l=1}^{m} p_{li} x_l$$

$s.t.$

$$\sum_{j=1}^{n} \lambda_j y_{kj} \geq y_{ki}, \; k = 1, \ldots, s;$$

$$\sum_{j=1}^{n} \lambda_j x_{lj} \leq x_l, \; l = 1, \ldots, m;$$

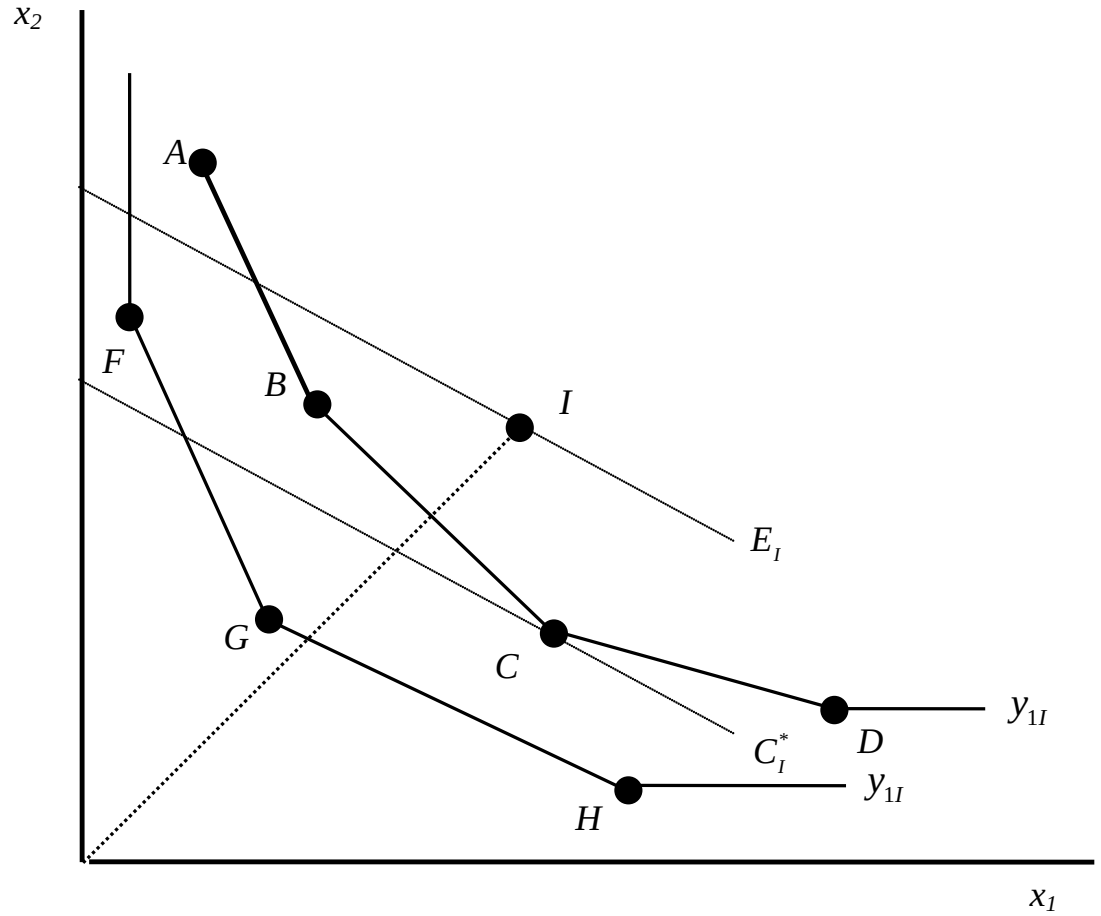
$$\sum_{j=1}^{n} \lambda_j = 1;$$

$$\lambda_j = 0 \text{ if } z_j > z_i, \; j = 1, \ldots, n;$$

$$\lambda_j \geq 0, \; j = 1, \ldots, n.$$

$$CE_i = \frac{\sum_{l=1}^{m} p_{li} x_{li}^*}{\sum_{l=1}^{m} p_{li} x_{li}} = \frac{C_i^*}{E_i},$$

Minimum Costs and the Socioeconomic Environment



Measuring Cost of Adequacy

- Adequacy requires predefined standards.

$$Y^A = (y_1^A, \ldots, y_s^A).$$

$$C_i^A = Min \sum_{l=1}^{m} p_{li} x_l$$

$$s.t.$$

$$\sum_{j=1}^{n} \lambda_j y_{kj} \geq y_k^A, \; k = 1, \ldots, s;$$

$$\sum_{j=1}^{n} \lambda_j x_{lj} \leq x_l, \; l = 1, \ldots, m;$$

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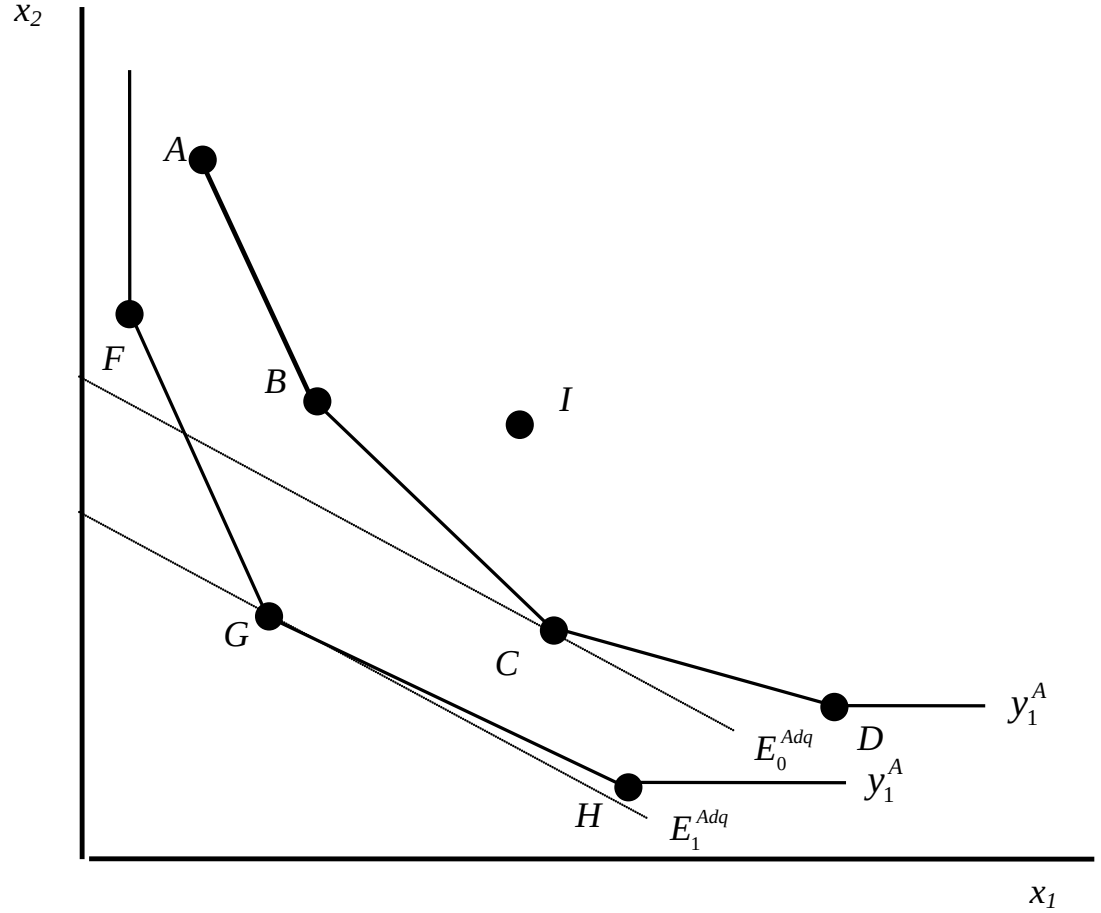
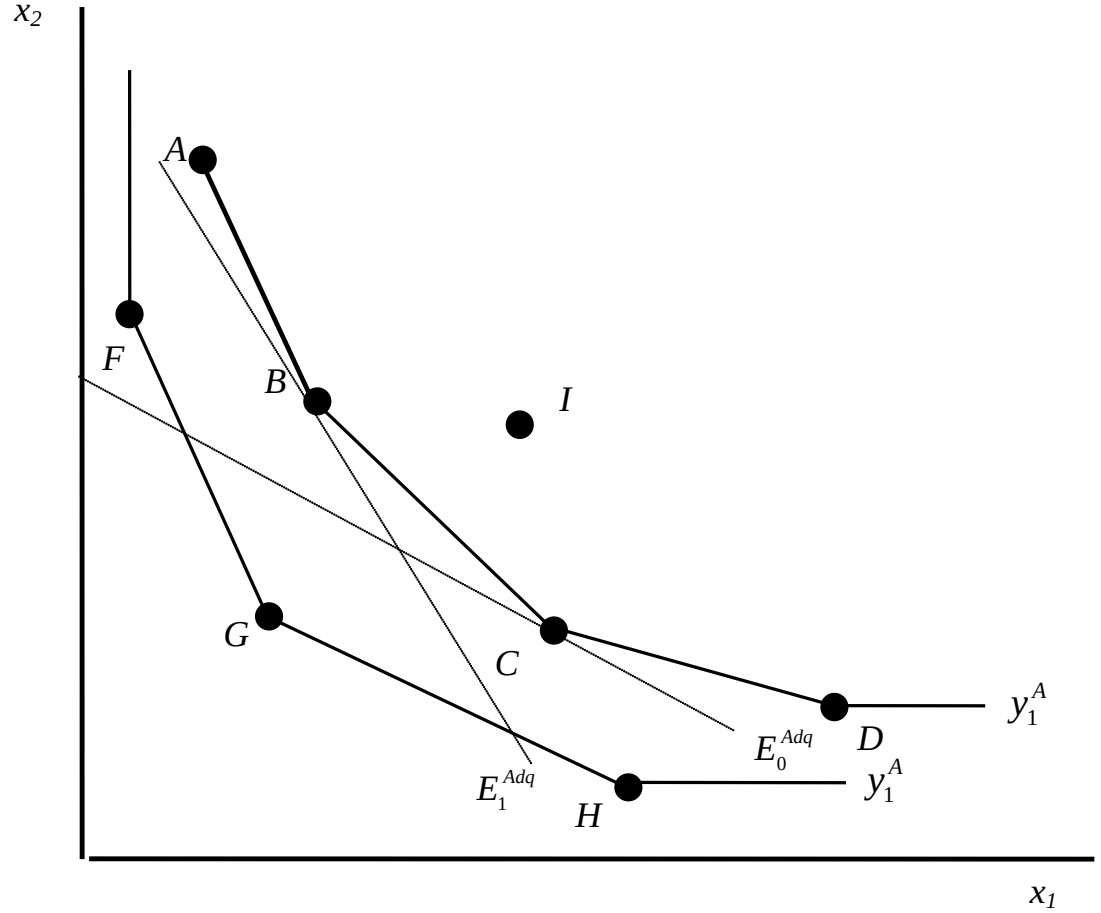
Adequate Expenditures with Identical Input Prices



Adequate Expenditures with Varying Input Prices



Application:
Dutch Schools

- Approximately 600 secondary schools in the Netherlands
- 4 levels of education (4,5, or 6 years of duration)
- National standardized examination for each subject in graduation year

- Schools are publicly financed
- Yearly lump-sum payment (budget)

Dutch Data

- Representative sample of 420 Dutch secondary schools
- Single year 2011/2012 (in short: 2011)

Student data for 2011 (Source: Min of Educ and Educ Inspec.)

- National examination grades (av=6.5)

  → Average per school for all students and all subjects
- Student achievement (av. 98)

  → progress in secondary education
- Economically disadvantaged students (av. 6.3%)

  → share of students from a disadvantaged area (status determined by Ministry)

Dutch Data II

- Three Outputs: # Students, National Examination Grades, Student Achievement
- Four Inputs and according Prices: Management, Teachers, Support Personnel, Material Expenses
- Environmental Factor: Economically Disadvantaged Students (%)

Descriptive statistics

Table 1: Descriptive Statistics (N = 420)

	Mean	Standard Deviation	Minimum	Maximum
National Examination	6.483	0.299	5.600	7.500
Student Achievement	98.818	6.536	68.519	123.505
Number of Students	1,831	1,017	174	5,641
Management Personnel (FTE)	6.672	6.391	0.700	49.300
Teachers (FTE)	119.219	67.959	15.800	379.700
Support Personnel (FTE)	38.104	24.490	2.900	125.900
Material Expenses ((1000s of Euros)	1,751.437	1,154.698	141.207	7,965.388
Average Management Price	106,123.81	31,682.94	23,614.80	250,39.88
Average Teacher Price	80,701.04	19,112.47	19,193.28	183,576.28
Average Support Personnel Price	25,276.79	8,711.75	6,374.67	83,151.96
Economically Disadvantaged Students (%)	6.31	11.31	0.00	97.20

All prices in Euros.

Adequacy standards

- Absolute standards, acceptable for schools
  - Student achievement=100 & av. grade= 6.5
- Relative performance, used by Dutch Education Inspectorate:

  < 25th percentile → 'fail'

  >75% percentile → 'good'

  >90% percentile → 'very good'

Adequacy Standards

Table 2: Adequacy Standards

Model	Percentile	Student Achievement	National Examination
1	25th	95.15	6.30
2	Absolute	100.29	6.50
3	75th	102.60	6.64
4	90th	106.14	6.90

Classes of environmental harshness

1. No disadvantaged students
2. Low share of disadvantagd students
3. ↓
4. ↓
5. High share of disadvantaged students

Results I

Table 3: Average Adequacy Costs per Student by Environmental Harshness

	Model			
Class	1	2	3	4
1	4,978	5,064	5,308	6,123
(87)	(87)	(87)	(87)	(87)
2	5,342	5,472	5,682	6,364
(85)	(85)	(85)	(83)	(75)
3	5,624	5,759	5,958	6,620
(81)	(82)	(82)	(79)	(68)
4	5,735	5,933	6,192	7,783
(82)	(82)	(81)	(79)	(56)
5	6,661	6,965	7,547	
(84)	(74)	(63)	(52)	----
All Schools	5,638	5,772	6,015	6,633
(420)	(410)	(398)	(380)	(284)

Results II

1. Differences in adequacy costs to achieve model 1 for class 5 is 1.4 x costs of class 1; ratio is 1.4 for model 3
2. Cost increase from model 1 to model 3:
    1. Class 1: 6%; Class 5: 12%
3. No school in class 5 has feasible results in model 4, and not all class 5 schools have feasible results for model 1.

Conclusions

1. Differences in adequacy costs for the five classes for the different performance standards are very large
2. Large differences in cost increase to reach 75th percentile
3. The number of schools with feasible results decreases for schools with a (very) unfavorable environment when adequacy standards increase