Education production functions (Part II)

EE473

Designing and interpreting education production functions

- Education production functions (EPFs) are a statistical technique used by economists to analyze a school's chosen production plan
- How efficient is one school's production plan compared with another?
- If a school were to alter its usage of certain inputs, could it increase the quantity and/or the quality of its output?
- As our review of the key assumptions of economic production theory revealed, the level of efficiency a firm achieves in its production is heavily dependent on having a clear and well-defined production goal, an entrepreneurial leader with decision-making authority, control over the production process, and the ability to select which inputs to use and which outputs to produce

A Conceptual Framework for the Education Production Process

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Accompanying this path model is a statistical model that economists use in their analyses of the education production process. This statistical model has the following functional form.

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + u$$

The **dependent variable** (Y) represents the output of the production function. Each EPF has one and only one dependent variable. The value of the dependent variable is said to be determined by the values of the **independent variables** (i.e. the Xs).

- ❖Choosing an Output and the Inputs
- ❖Multiple Outputs and Multiple Output Measures
- ❖Comments on the Statistical Estimation of EPFs
- ❖Interpreting an EPF

Choosing an Output and the Inputs

Choosing an output involves three basic steps.

1. Identify the school's production goal -The production goal will determine the output used in the EPF
2. Identify the data best representing that production goal
3. Determine what data is available and examine how it represents the production goal

Identify the school's production goal

The economist must determine how that output will be measured. Take the case where the school's goal is to maximize student academic achievement.

- ❖ How exactly does the school measure academic achievement when it tracks its progress toward its production goal?
- ❖ They could use course grades, local, state or national standardized test scores, or teacher reports of academic achievement
- ❖ Another dimension along which schools assess achievement is subject area - Is the school more concerned with some subjects than others?
- ❖ Again, the economist should collect data on the output most closely related with the school's production goal
- ❖ If that goal targets the performance of all students in mathematics and reading, these should be outputs the economist uses in his EPF.

The inputs included in an EPF should be those present in the school's production plan

- Recall, economic production theory assumes firms are able to select which inputs they use in their production process and the quantities used of those inputs
- Education production inputs are typically classified into three main groups: school and classroom, family and student, and social context
  - School and classroom inputs are those specific to and thus characterize individual schools and classrooms
  - Commonly used inputs include school size, number of books in the library, average class size, and strength of principal leadership
  - Classroom specific inputs characterize the production process within individual classrooms
  - These include inputs such as teacher quality, amount of instructional time, and instructional materials
  - The degree to which the school can select how much of these inputs to use in their production process varies across input as well as across schools

Family and student inputs are specific to individual students and their families

- These are characteristics of students and families that influence the education production process
- Economists commonly use measures of the family's socio-economic status such as family income and parental education attainment
- Other family inputs could include how many books are in the home, how many days a week the entire family eats dinner together, or the number of minutes each night the parents help their child with homework
- Student inputs frequently used in EPFs include the student's prior learning, age, race, ethnicity, and gender. Public schools have very little, if any, control of the use of these inputs in their production process

Social context inputs are those determined by the community in which the school is located and that influence the production of education

- Crime rates and unemployment rates are examples
- High unemployment rates could reduce the motivation of students to succeed in school as they feel trapped in their dismal situation
- Or, high unemployment rates could increase student motivation to succeed in school as they see academic success as their means out of their current undesirable situation
- A school's community may be more expansive so as to include a state or a country. Therefore, this category may include those inputs whose use in the education production process is required by state or national mandates

- Given the scope of the education production process, we will never capture all the inputs in a school's production plan
- We must, however, identify the essential inputs
- For this it is helpful to think about these three broad categories when selecting the set of inputs for inclusion in an EPF
- In selecting which inputs and outputs to include in an EPF, the economist must confirm that the variables have sufficient variability
  - **Variability** is a measure of how the values of a variable differ across observations in a sample or population.
  - Recall, the EPFs tell us how changes in inputs are related to changes in outputs. They relate variability in the inputs to variability in the output
  - Therefore, if there is no variability in the input and/or the output, the economist can not make any statements on how changes in the inputs are associated with changes in the output
  - Such a statement requires there to be change, yet without variability, there is no change.

Example

An economist is interested in how differences in years of teaching experience are related to student test scores in mathematics. He believes that teachers with more experience are better equipped to elicit strong test performance from students than newer teachers. Assume that all teachers in the sample have five years of teaching experience. The economist can not say anything about the effect of changes in the number of years of teaching experience on test performance because his sample has no variability in the input.

Multiple Outputs and Multiple Output Measures

- The assumption that firms have one clear and well-defined production goal does not necessarily apply to schools
- Schools frequently have multiple goals, such as to maximize academic achievement and graduation rates and minimize substance abuse rates
- Each additional goal increases the complexity of a school's production plan
- Recall that production plans instruct the firm on how to most efficiently meet its production goal
- Multiple goals pose several challenges to an economist.
- We will discuss two related challenges—differing production processes and multiple measures of production goals

Consider a school with two production goals—maximize student academic achievement and minimize dropout rates. How do the production processes for each of these goals compare? Do they require the same inputs? The input of school size is an illustrative example. A larger student body can increase the amount of course offerings available to students. More courses improve the school's ability to provide instruction catering to specific learning styles, interests, and abilities and hence can lead to stronger student performance. Therefore, the production plan for the maximization of student academic achievement would instruct the school increase the size of its student body. What student body size does the production plan for minimizing dropout rates call for?

- This example shows that the actions a school undertakes to meet one production goal (maximize student achievement) may conflict with the actions it needs to undertake to achieve another production goal (minimize dropout rates)
  - And given that a school's student body size is fixed, the school is forced to make a trade-off between the two production goals
  - This is the first challenge arising from multiple goals
  - In order to fully capture the production process at a school with multiple production goals, an economist must estimate a separate EPF for each output
- The second related challenge is how to deal with multiple measures for any given production goal. Maximizing student academic achievement is a great example. There are test scores in a variety of subjects and for a variety of grade levels. Rarely are data available for all subjects and all grades.

- These two challenges illustrate the importance of data to EPFs
  - The accuracy of the results is directly linked to the accuracy and completeness of the data
  - While EPFs provide valuable insight into the education production process, economists must be careful in interpreting their EPF results as supportive of specific policies and programs

Comments on the Statistical Estimation of EPFs

- All education production functions are a form of a statistical technique called **multivariable regression**
- A **population** and a **sample** are two related concepts referring to the group being examined in any empirical research. The population is the group affected by the phenomenon of interest to the researcher. A sample is a smaller group selected from the larger population who will be examined in a particular study.
- A sample is assumed to be representative of the entire population. This allows the findings from the sample to be generalized back to the entire population. Findings are said to be **generalizable** when the results based on the sample are true for the entire population. A **random sample** helps ensure that the sample selected is representative and unbiased.

- **Selection bias** is a common problem with much of the education research seeking to examine the effects of some educational **intervention** such as a special program or policy.
  - These could be interventions such as curricular programs, teacher training programs, policies to involve parents in school governance, and reducing class sizes
  - In this group of EPFs, economists compare production in schools with the intervention to those schools without it
  - Any revealed efficiency differences between the two groups of schools are attributed the intervention For example, the EPF reveals students in schools with a particular math curriculum outperform students in schools using other curricula
  - The economist attributes these efficiency gains to the curricular intervention.
- Selection bias arises when the two groups differ significantly on some characteristic, other than the presence or absence of the intervention, which is itself related to the output. Consequently, the efficiency gains revealed by the EPF may not result from the intervention, but rather from differences in this other characteristic.

Randomized assignment techniques are one way of preventing selection bias

- The concept is similar to randomized sampling in that the intervention is randomly assigned to schools
- This technique helps ensure that the group of schools with the intervention does not differ systematically from those schools without the intervention
- Randomized sampling is a highly controversial topic in education research due to ethical and methodological issues

Interpreting an EPF

Carnoy, M., J. Marshall and M. Socias (2005). "How Do Schools Influence Math Scores? A Comparative Analysis", Stanford University, working paper.

- An analysis of eighth grade mathematics achievement
- The authors assume that that the schools included in this study have identified the maximization of math test scores as a production goal
- The authors are interested in how the schools make use of the educational resources available to them in their production process

They create a series of variables to represent the students' opportunity to learn

- **Opportunity to learn** is conceived as a measure of how much classroom time is spent in educational activities such as small group projects, worksheets, computer activities, homework review, and testing
- Educational theory predicts that increases in the opportunity to learn provided to students will lead to increases in their academic performance
- In order to test this theory, the authors make the assumption that the schools have the decision-making authority to vary their use of the "opportunity to learn" input.
- The study compares how opportunity to learn is used in the education production processes across numerous countries in North and Latin America, Europe and Asia using data from the TIMSS - Within each country that participated in TIMSS, random samples of students were selected.

For each country, the authors estimate the following EPF:

$$A = a + (b_1 \times P_1 + \ldots + b_7 \times P_7) + (c_1 \times X_1 + \ldots + c_{18} \times X_{18}) + (d_1 \times S_1 + \ldots + d_6 \times S_6) + U$$

The output A is each eighth grade student's mathematics test score. It is regressed on a group of seven variables (P1 through P7) representing characteristics of the students and their families, a group of eighteen variables (X1 through X18) representing school and classroom inputs, and a group of six social context variables (S1 through S6). Recall that the U in the equation is the error term.

An Example of Results from an Education Production Function

Variables	Germany	Korea
Student and Family Characteristics:		
Student Female (b_1)	-1.85	-0.97
Home has computer (b_6)	0.06	1.44
School and Teacher Characteristics		
Opportunity to Learn:		
Testing (c_3)	-1.96	0.34
Work on Project (c_4)	-2.38	1.04
Use Worksheets (c_5)	-1.59	0.60
Use Computer (c_6)	-1.49	-2.78
Problems from Everyday life (c_7)	1.06	0.33
Work in small group (c_8)	1.23	0.86
Discuss Homework (c_9)	0.63	-0.81
Social Average Grade 7 (c_{10})	0.54	0.23
Social Context:		
Located in Suburb (d_5)	0.62	0.56
Located in City Center (d_6)	-0.88	1.02
Observations	1,273	2,672

❖The interpretation of a specific parameter for a given input requires that all other inputs be held constant, ***ceteris paribus***

Student and Family Characteristics

❖The value of the b1 parameter is negative for the EPFs for both Germany and Korea. This indicates that when the value of *student female* increases by one unit (i.e., from 0 to 1) that the math test score decreases in value.

❖In Germany, female students on average score 1.85 points below male students, holding all else constant.

❖The EPF results show that students in Korea with computers in their home (i.e., the dummy variable *home has computer* = 1) receive scores 1.44 points higher than student without a computer at home.

Social Context

Differences in the education production processes between schools located in urban, suburban, and rural areas are another common line of research in the EPF literature Students in urban schools in Korea have math test scores that are 1.02 points higher than rural schools on average, ceteris paribus. (Recall located in city center equals 0 for rural schools). And Korean students in suburban schools have average math test scores that are 0.56 points higher than students in rural schools, ceteris paribus. (Again, remember that located in suburb equals zero for rural schools.

The next logical question is how do average math test scores compare between schools in urban and suburban areas? The answer is d6 – d5. To see this, solve the following equation:

Change in A = d6 × (located in city center = 1) – d5 × (located in suburb = 1) = (1.02 × 1) – (0.56 × 1) = 0.46

Therefore, students in urban schools in Korea outperform students in suburban schools by 0.46 points, holding all else constant.

School and Teacher Characteristics

When economists use EPFs to examine the production of academic achievement, it is very important that they include a variable for previous academic achievement. Schools that have access to students with higher previous achievement are likely to have higher achievement than schools serving students with lower previous achievement. In this example, the EPF examines the production of eighth grade mathematics test scores. The authors capture the use of previous achievement as an input in the production process by including the continuous variable *school average grade 7*. This measure the average math test score among seventh graders at the school.

The c10 parameter represents the effect of previous achievement on eighth grade mathematics test scores. In Germany, average eighth grade math scores increase by 0.54 points for every one point increase that school's average seventh grade test score. This effect is more than double the effect of previous achievement in Korea.

Finally, what insights do the EPF results provide regarding the authors' research question? Do students with more opportunity to learn have higher math test scores than students with less opportunity to learn? The authors measure opportunity to learn through a series of seven continuous variables that measure how much classroom time is spent on various learning activities.

Examining the EPF results for the c3 through c9 parameters reveals that, everything else constant, some activities have a positive effect on math test scores and others have a negative effect. The results also indicate that the directions of the effects are different in Germany and Korea for several activities. In German schools, average eighth grade math scores decrease as students spend more time in the classroom taking tests, working on projects, and using worksheets. However, in Korea math test scores increase as students spend more classroom time on these activities. The results also show that the positive effect on test scores of increasing the time students spend working on problems related to their everyday lives is almost three times the effect in Korea, all else constant. These findings suggest the education production process in Germany differs from that in Korea.