CHAPTER 3: EDUCATION PRODUCTION FUNCTIONS

TABLE OF CONTENTS

INTRODUCTION

Most people are not familiar with the concept of **education production functions**, but almost everyone is familiar with some of their findings. For example, many news stories have been written about students in smaller classes doing better in schools. Almost everyone that has a child in school knows that governments and schools try to improve student performance by requiring teachers to teach certain curricula or use specific instructional techniques or require that each classroom is equipped with a computer with Internet-access. These education policy decisions may have been based on research findings from education production functions.

A major focus in the economics of education is the study of the production of education, of how schools use a set of inputs, say teachers, textbooks, and computers for example, to produce an educational good such as test scores, school attainment, or student engagement. The fundamental analytic tool economists use in this line of work is the education production function. At the most basic level, these functions are intended to show how much of the educational good, or **output**, can be produced from specific amounts of a certain set of **inputs**.

For example, an economist would use an education production function to predict how students will perform on a science test. In analyzing science test performance, the economist would be interested in research questions of the following type:

1. Do students who receive at least 50 minutes of science instruction five days a week receive higher scores than students receiving less than 50 minutes of science instruction a day?
2. Do students whose science instruction includes a textbook published in the last two years outperform their peers who have access to older science textbooks?
3. Do students taught by teachers with advanced scientific training score higher on the exam than those students taught by teachers lacking such training?

To answer each of these questions, the economist would estimate an education production function to determine how a specific input (daily instruction time, textbook, teacher training) is combined with other inputs to produce a specific output (science test scores).

The economist's findings regarding each of these questions can inform the education policy-making process as to which policies should be implemented by governments and school administrators. If the results reveal that test scores are higher when teachers have the advanced training, one could argue for the implementation of an education policy requiring all science teachers to have a master's degree in science. Policymakers supporting such a policy would believe that once all science teachers have completed this advanced training student tests scores will increase. They would base this belief on the results of the education production function. However, care should always be taken when jumping from research findings to public policy.

The validity of any research finding from an education production function assumes that the economist has accurately captured in his education production function all the inputs used in the production process of science test scores. If you were asked by the economist conducting this study to list the educational inputs that influence a student's score on the science test, what would you put on your list? The first set of inputs would be those of particular interest in this study – amount of science instruction received each day, publication date of the textbook, and level of the teachers' scientific training. But clearly these are not all the inputs.

Aspects of the school environment (e.g., quality of the science classrooms, principal leadership, etc.), the classroom (e.g., number of students, student behavior, etc.), the community (e.g., level of support for schools), and each student's family (e.g., parental education attainment, household income, etc.) all presumably exert some influence on how a student performs on the science test. Assuming it were possible to even list all the inputs, it is unlikely they can all be measured in some quantifiable way in order to be included in a statistical equation. Strong principal leadership, for example, is certainly related to a school's success, but what exactly is it about the leadership style that influences test scores? And how would we measure those aspects? Also, the home lives of students play another significant role in student performance. To accurately measure a student's home life, researchers would need to visit each student's home. Yet this surely is not feasible.

In order to study the complicated **education production process**, economists make many simplifying assumptions. These assumptions are taken from classical production theory that guides the economic study of the production process in a firm. As a group, these assumptions provide a framework for examining and explaining behavior. For example, a key assumption of production theory is that firms have a clearly stated goal toward which all their actions are directed. It is usually assumed that a firm's goal is to maximize its **profit**. This **profit maximization** assumption implies that the firm will consume a set of inputs that minimizes costs while still producing a product that the firm can sell in the market and turn a profit. Without this assumption, what would guide the firm's input use decisions? Are their decisions just pure happenstance? Is it possible to model happenstance?

When the assumptions of classical production theory are applied to the educational system, economists need to examine their applicability to the production of education. What is a school's production goal? Profit maximization does not seem an appropriate assumption. Is there another goal guiding the actions of schools? Returning to our economist examining the production of science test scores, is it appropriate to assume that schools seek to consume a set of inputs (e.g., instruction time, textbooks, and trained teachers, etc.) in order to maximize student test scores? These are the types of questions that must be explored prior to using an education production function. Based on the answers to these questions, simplifying assumptions must be altered where needed to enable an economic study to accurately capture the education production process and for its findings to correctly inform the policy making process.

This chapter is organized into four main sections. We begin with a discussion of the role of assumptions in economic analysis. Next, we review the assumptions of production theory and explore their applicability to the production of education. Specifics on how to design and interpret the findings of an education production functions are discussed in the third section.

The final section presents two additional analytic tools intimately related to education production functions. Cost- effectiveness and cost-benefit analyses take results from EPFs and relate them to costs. For example, say that our economist finds that using newer textbooks is associated with a ten point increase in science test scores while having teachers with advanced training is associated with a fifteen point increase. Should the economist recommend that schools provide advanced training to all its science teachers on the basis of these results? Not necessarily. It may be that the additional five points achieved by the advanced training are not enough to justify the training's cost. It could be that purchasing new textbooks achieves higher test scores at a much cheaper cost. Cost-effectiveness and cost-benefit analyses are powerful tools economists use in conjunction with education production functions to inform public policy.

LEARNING OBJECTIVES

After careful study of the material contained in this chapter, the student should be able to:

1. Explain the key assumptions of economic production theory and how they apply to the production of education
2. Identify key educational inputs and outputs that ought to be included in an education production function
3. Interpret the results of a simple education production function
4. Explain two analytic techniques for comparing the effects of educational programs and policies

PLAN DE TRABAJO

To develop the skills listed above, you should read each section and then undertake the activities listed at the end of each section or sub-section. The activities, necessary steps, approximate time, and resources you will need are listed below.

Activity	***Steps***	***Estimated Time***	***Necessary Resources***
Section 1 Questions	Read and answer questions at the end of Section 1.	1 hour	1. Section 1 of this chapter
Section 2 Questions	Read and answer questions at the end of the five sub-sections.	3 hour	1. Section 2 of this chapter
Section 3 Questions	Read and answer questions at the end of the five sub-sections.	2 hour	1. Section 3 of this chapter
Section 4 Questions	Read and answer questions at the end of Section 4.	1 hour	1. Section 4 of this chapter

1 THE ROLE OF SIMPLIFYING ASSUMPTIONS IN ECONOMIC ANALYSIS

One of the most common criticisms directed at economics from non-economists and those approaching it for the first time focuses on the simplifying assumptions that all economic theories and statistical models rely on to make predictions about human behavior. The criticism goes something along these lines. "We agree that human actions are guided by complicated and complex processes. Yet, in order to study past actions to make predictions about future actions, your models impose assumptions that intentionally simplify those actions. Consequently, you aren't actually modeling true complicated and complex human behavior but rather some simplified version. Therefore if the purpose is to explain and predict human actions, economics provides no useful insight." While the central concern expressed in this criticism—that economic models capture a simplified version of reality—is not without merit, its conclusion is incorrect.

An economist would respond by asking the critic to realize that we rely on simplifying assumptions whenever we make predictions about any social phenomenon. For example, as an instructional technique, a mathematics teacher tells her students that once a week she will give them a pop quiz. The teacher believes that the prospect of a pop quiz will motivate her students to study and stay on top of the material in order to be prepared for the quiz, whenever it should be administered. She feels that without pop quizzes her students will wait until just before the final exam to study the material. A model of this phenomenon would predict that students facing random pop quizzes will perform better on a final exam than students in a class without pop quizzes. The simplifying assumption is that students want to get a high grade in the class. If the students want to get a high grade, they will realize that they must do well on the quizzes which in turn prepare them for the final exam. A related assumption is that students who continually study and review the material throughout the course will receive higher final exam scores than students who only study and review the material in the few days immediately prior to the final exam. Without these assumptions, the likelihood of failing a pop quiz will provide no motivation to students to study and thus students will be poorly prepared for the final exam.

Yet the skeptics among you may still be dubious about the use of simplifying assumptions. You may be thinking, "The usage of simplifying assumptions is not necessarily justified just because I frequently use them to explain and predict human actions. In many cases these simplifying assumptions do not hold." It is true that assumptions do not always hold, but this does not automatically disqualify them from use in economic theories and models. Instead these instances where the assumptions fail provide an excellent opportunity for further study of the assumption itself.

In the example of the mathematics teacher giving pop quizzes, there are likely some students in the class who are not motivated to get a high grade in the course. Our simplifying assumption does not hold for them. If we relax this assumption so that students no longer necessarily want a high grade, what are our explanations and predictions of human actions? How do they compare to our explanations and predictions when the assumptions hold? While this topic is too advanced for this course, economics models allow for this line of research and in doing so, provide further insight into whatever phenomenon is being studied.

To better understand the vital role these simplifying assumptions play in economic analysis, consider the following metaphor in which the economist is viewed as a cartographer. As the cartographer explores terrain in order to create a detailed map, the economist explores a social phenomenon in order to explain and predict behaviors and actions. The set of simplifying

assumptions serve as the economist's reference point or base camp. In order to fully map an area's terrain, the economist first establishes a base camp and becomes intimately familiar with its features. It will serve as the starting and ending point for all her explorations into the surrounding terrain. Before beginning an exploration, she relaxes a simplifying assumption, sets her coordinates, and sets off. On some explorations she will encounter new things and on others she will see more of the same. The detailed map is created by comparing everything she sees and experiences on her explorations to what she sees and experiences at base camp. It may be the case that these comparisons highlight limitations of her current base camp. Consequently she changes the location of her base camp (i.e., simplifying assumptions) to a location from which she can better explore and map the terrain.

Prior to exploring the terrain of any given social phenomenon, a framework must be established in which the terrain can be analyzed. Assumptions establish this framework for the economist. (In fact, research in most disciplines such as sociology, political science, psychology, and anthropology rely on assumptions.) Without them, the economist would not know where to begin. Yet, economic analysis need not be limited by them as the cartographer metaphor illustrates.

1.0.1 Activities for this Section

1. What role do assumptions play in economic analysis?
2. Consider a researcher studying how bees make honey. What would be some important simplifying assumptions the researcher might make to guide her study?

2 ASSUMPTIONS OF THE PRODUCTION PROCESS

In this section, the key assumptions of classical production theory that establish the framework for economic analyses of production are reviewed and their applicability to the production of education is discussed. When economists study production, they consider an industry and examine the behavior of the individual firms in that industry. To illustrate these assumptions of production theory, we will examine the behavior of a restaurant in the food industry. When production theory is applied to education, individual schools are viewed as firms and the school system as the industry.

Each assumption will be discussed in turn. We begin with the assumption that a firm has a clearly defined *production goal* toward which the firm's behavior is directed. Leading the firm towards this goal is assumed to be an *individual (or group of individuals) with decision-making authority*. This decision-making authority allows for *control over the entire production process* including the *selection of inputs*. A firm's internal behavior is assumed to be restricted by the fact it *faces competition from other firms* in both the market for the inputs to its production process and the consumer market for its output or product.

2.1 Goal of Production

Anything worth doing should have a purpose. It should help you achieve whatever it is you want. If you want to arrive safely at your home after a dinner with friends, you turn on your headlights at night so you can see where you are. If you are scheduled to have surgery tomorrow morning, you follow the doctor's pre-op orders to avoid all liquids and solids after 6pm because you want the operation to go successfully. In each situation, you set a goal—arrive home safely,

have a successful operation—and take certain actions to achieve it. Economists apply this same logic to firms.

Firms are assumed to have one clear, well defined **production goal**. Furthermore, it is assumed that the firm's actions are all purposely undertaken in order to achieve that goal. This goal is typically assumed to be profit maximization. Profits are defined to be the difference between revenue and costs. They are seen as essential for a firm's survival in the marketplace. Profits provide resources that can be reinvested in the firm so that it can remain competitive. Profits can be reinvested in many areas such as to replace and upgrade equipment, increase wages to attract high-quality workers, and expand research and development activities that could improve the product quality. Profits also send a signal to external actors that it is a solid investment opportunity. Firms will want to maximize their profits so as to reap these and other benefits. Therefore, firms will direct all their actions toward achieving this goal. However, firms need not have profit maximization as their production goal.

Cost minimization is another potential production goal for some firms. A public service organization that delivers free meals to elderly shut-ins is an example of such a firm. The employees of this organization know that they must provide meals for 100 senior citizens each day. These 100 meals must meet certain quality and dietary standards. This organization is funded through contributions from the public which are not received on a regular, predictable schedule. Consequently, this organization seeks to produce and deliver the meals to the 100 senior citizens as cheaply as possible and hopes that the public contributions will cover the costs. Any cost-savings can be used to cover future shortfalls. The organization knows that if they fail to control their production costs, they will be forced to cancel their service. Consequently, this organization will direct all its actions toward the goal of minimizing its costs so that their customers do not go hungry.

Regardless of which specific production goal a firm has, the goal is clear and well-defined. It tends to be set by one person such as the owner, CEO or president or by a specific group of people such as the board of directors or trustees. Once the goal has been identified, the firm can devise a production plan designed to achieve the goal. To help provide some intuition behind this assumption, let's examine how it applies to our fictitious restaurant.

The restaurant, *Understated Excellence*, is located in a busy commercial downtown district. It serves lunch and dinner six days a week with brunch and dinner on Sunday. Michael Rudolph, the owner and head chef, opened the restaurant six months ago. Having worked in other restaurants since graduating from culinary school, he craved an outlet for his culinary creativity. He wanted to design his own menu and to share his love of fine foods with others. Michael has visions of opening other restaurants, each catering to a specific palate.

Michael, as owner, has clearly stated in his business plan that profit maximization is the production goal at *Understated Excellence*. The business plan, a requirement for the small business loan Michael received from his bank, details how the restaurant will operate. It holds Michael responsible for directing his and the actions of his staff toward achieving that goal. Profits will provide Michael the ability to realize his personal dreams and goals. Besides keeping the restaurant open, Michael will use the profits to increase the restaurant's menu offerings. The profits will finance culinary experiments aimed at creating unique and delicious new dishes that only *Understated Excellence* will have and for which the public will patronize *Understated Excellence*. These experiments are risky of course as some of the new dishes will never appear on the menu. Consequently, Michael will have to rely on the successful experiments—those that are added to the menu—to recoup the investments he made in his culinary research and

development. The business plan also states that Michael intends to save a portion of the profits to finance the opening of additional restaurants.

Now let's apply the assumption that a firm has one clear and well-defined goal to a school and its production of education. What is a school's goal for the production of education? Who identifies that goal? Do schools have a production plan that details how they will achieve that goal?

Can either of the two most common production goals assumed for firms—profit maximization and cost minimization—be assumed as the goal of a school's production of education? Schools, almost without exception, are not profit maximizers. They do not realize monetary profits which they then reinvest in their production process to expand their curricular and extracurricular offerings. It is certainly true that schools seek to make such investments, but these investments are not financed by profits generated by selling their product to customers for a higher price than what it cost to produce.

Fundamentally, a school's goal of education production is cost minimization. Recall the public service organization that knows they must provide 100 senior citizens with meals meeting a set of minimum quality and dietary standards. They also must provide these meals within a minimum cost in order to ensure there will be enough finances coming in through public contributions to maintain production. Analogously, most schools are funded through public funds collected in the form of taxes levied on the public by national, state, and local governments. Schools also know they must provide an education to a given number of students. Therefore it seems reasonable to assume that a school's goal of production is *to provide a quality education to all its students at minimum cost*. However, whereas there is a set of clear and well-established health and dietary standards to define the minimum quality for the meals provided by the public service organization, the standards defining the minimum quality for the education provided by a school are less definitive and thus prone to varying interpretations. It is this question—"What characteristics does a quality education have?"—that prevents schools from identifying one clear and well-defined goal to guide their production process.

Educational quality means different things to different people. In broad terms, people define educational quality as providing children with the necessary skills to be successful in life. Yet, they disagree on what comprises those "necessary skills" and on what deems a life "successful". Some argue that the necessary skills can been confined to the basics—language, writing, and mathematics. Others hold a more extensive view of "necessary skills" to include other academic subjects as well as curriculum in such areas as character and moral development, nutrition and physical health, and civic mindedness (e.g., political involvement and volunteerism). If a school used the former definition of necessary skills, they would cut their science, history, and arts curriculum to reduce production costs. However, if the later and broader definition were used, schools would seek increased public funding to expand their curricular offerings in order to meet this standard for educational quality. If a "successful" life is one where the individual is happy, how can schools tailor their production process so that its students can achieve their own concept of happiness over the course of their lifetime?

The identification of one clear and well-defined goal of production is further hampered by the presence of more than one decision-maker. At the restaurant, the decision-maker is the owner Michael Rudolph. He established the firm's production goal and wrote a business plan to achieve that goal. Yet, for a school, there are many disparate decision makers involved in setting the school's production goal and drafting its production plan. There are many ramifications from this diffusion of decision-making responsibility that will be discussed in greater detail in the next

section on the organizational structure assumption of classical production theory. However, here we will focus only on the ramifications for the goal-setting process.

Education policy is determined by actors on multiple levels from governing bodies (state, local, and national) to school officials (principals and teachers) to parents to business and community leaders. Each level may define educational quality differently and thus have a different production goal. For example, the national government could establish the goal of maximizing student academic performance while the state government could insist that students graduate from secondary school. School officials set the goal that students should attend school regularly. Parents could set a goal that schools expose students to the fine and performance arts. Finally, public safety officials could insist that a quality education dissuade students from involvement in vandalism, substance abuse, and other crimes.

It should be readily evident that embedded in each of these goals is at least one performance measure intended to provide assessment information on how successful the school has been with respect to achieving the goal. The national government could require that all students take end-of-year examinations in mathematics and language arts. The state government could require all secondary schools to annually report graduation and dropout rates. In order to meet the production goal established by local parents, schools would require that each student complete a specific number of courses in the fine and performing arts. Public safety officials would analyze incidence rates of youth-perpetrated crime.

With such multiple and potentially competing production goals and their associated performance measures, it is much more challenging for a school to devise one production plan that can achieve all goals. Back at the restaurant, Michael Rudolph devised a business plan that detailed the design of the production process. It ensures that all the firm's actions are directed at achieving the goal of maximizing profits. The absence of a clear definition of a quality education leaves to the school with a set of goals that may not necessarily be achievable with one production plan. In fact, we often hear school officials lament that their resources are spread so thinly that it is impossible to achieve the diverse set of goals set for them.

For example, actions that the school must undertake to maximize test scores analyzed by the national government may conflict with actions needed to achieve the goal established by the parents (i.e., that students be exposed to the arts) and the goal imparted by the public safety officials (i.e., that youths be dissuaded from criminal activity). Assume each goal requires the following actions:

TABLE 1: Actions and Associated Production Goals

Goal	Action
Maximize academic performance	One hour of instructional time in each of the tested subjects each day
Expose youth to the fine and performing arts	45 minutes each week in each discipline, fine arts and musical arts
Reduce youth-perpetrated criminal activity	One hour once a month of instructional time on the negative consequences of various criminal activities

You can see that these goals place demands on a significant portion of the time students spend in school. This leaves little time for other school activities, such as instruction in non-tested subjects, physical education, lunch and recess. The actions also require that schools fund these activities. Consequently, schools have less funding and less flexibility in allocating funds

to the other aspects of their education production process. It could very well be that cuts in one area of the production process have a negative impact on another area.

Putting together one production plan that enables a school to achieve its multiple and potentially conflicting production goals is a very challenging mandate. When using an education production function, the analyst must carefully examine how the educational outcome being analyzed—college attendance rates, for example—is aligned to the goals of the school. If the outcome and the goals are well aligned, it is a safe assumption that the productive actions the school undertakes are associated with the outcome. For example, if the school's goal is to maximize academic achievement, its actions directed at achieving that goal would also lead to more students enrolling in college. (It's easier to get into college with good grades and high test scores.) However, if the school's goal is to maximize graduation rates, it could be that schools relax academic standards in order to increase the graduation rate. This could leave students less prepared for college and cause fewer of them to enroll. In this instance, the analyst would be in error to assume that the school's actions are intended to maximize college enrollment rates. The consequences of this error are discussed later in this chapter.

2.1.1 Activities for this Sub-Section

1. What role does a clearly defined production goal play in the production process?
2. What is the definition of a successful firm?
3. Explain why it is difficult for schools to have one clearly defined production goal. What effect does this have on a school's chances of being a successful firm?

2.2 Organizational Structure

In the previous section, we discussed the central assumption that any productive firm has a goal for their production process. A clearly defined and stated goal enables the firm to focus its productive activities on a specific goal. A successful firm was defined as one that achieves this goal. We examine in the section that follows several assumptions regarding the organizational structure that economic theory posits as necessary conditions for a firm succeeding in meeting its production goal. Specifically, these assumptions are that the firm has an **entrepreneurial leader** with **decision-making authority**, the firm has control over the production process, and the firm can select what outputs to produce and which inputs to use in the production of those outputs. Although interconnected and interdependent, these three characteristics of the firm's organizational structure—leadership, control and selection—will be discussed in turn below.

2.2.1 Leadership and Decision-making

Behind any successful endeavor is a strong and decisive leader who takes charge of the reigns, provides direction and encouragement to others, and makes the tough decisions to ensure that the firm remains on the track to success. An essential trait in these leaders is their entrepreneurial spirit. Their drive to succeed is manifested in their constant search for new opportunities and processes to be stronger, faster, better. Complacent would not be an adjective applied to these leaders.

Michael Rudolph has a dream to grow his business to include several restaurants located in a variety of markets that cater to an array of food connoisseurs. In order for this dream to become reality, Michael is going to be a very busy man. He will need to work long hours at *Understated Excellence* developing new items for the menu, scrutinizing the quality of both the

ingredients and the meals, reading up on the latest industry trends, and conversing with customers to better understand what they like and dislike. Michael will need to carefully examine his production costs (e.g., the cost of ingredients, employee wages, electricity and other utilities, sales and property taxes, etc.) and his revenue stream. If he is to expand, his gross revenue must exceed his costs. This is a very delicate balance as Michael can not simply increase the prices on his menu to cover his production costs. Michael needs to somehow determine how much his customers are willing to pay for the food he produces and needs to make sure that there are enough customers willing to pay that price to keep his restaurant full and profitable. It's hard to imagine why anyone would want such a job. What would drive a rational individual to undertake such a demanding and time-consuming role? The answer in one word, incentives.

Economic production theory assumes that leaders are driven by rewards and sanctions. Rewards are bestowed on leaders who exhibit good performance, while sanctions are levied against those who perform poorly. But what do we mean by 'good' and 'poor'? These are normative judgments and thus open to different interpretations. What I consider a poor performance, you may consider a good performance. A source of our disagreement may be that we are basing our judgments on different standards. Thus, economic production theory restricts the basis of these judgments to the degree to which the firm achieves its production goal. Leaders who adeptly guide their firm through the production process to the achievement of its production goal are deemed to have performed well and are rewarded with salary increases, extra vacation time, stock options, etc. Leaders of firms that fail to meet their production goal are vulnerable to sanctions such as a salary reduction or being removed from their leadership post either by demotion or firing. And by being fired, the leader not only loses her job, but also the rewards that she would have received had she performed well.

A related issue is who is making the performance judgment. In many large firms, this role is fulfilled by a board of directors who have the authority to hire and fire the firm's CEO or president but are not personally involved in the day-to-day management of the production process. The Board of Directors, who are responsible to the firm and not beholden to the CEO, is able to objectively judge the CEO's performance. However in smaller firms the owner must pass judgment on her own performance. Can the owner judge herself objectively? Does not everyone want a higher salary and more time off? What's to stop the owner from incorrectly judging her performance as good and rewarding herself accordingly?

Take Michael Rudolph for example. The restaurant's goal is to maximize profits in order to finance an expansion into other markets. Good performance on Michael's part would mean that the restaurant is profitable while poor performance equates to minimal or negative profits (i.e., the company is losing money). Michael is keenly aware of the relationship between costs, revenue and profits.

Performance-based rewards represent an increase in production costs. Increases in production costs must be offset by an increase in revenue or else the restaurant's profits decrease. If *Understated Excellence* is already loosing money, any reward Michael awards himself in spite of his poor performance will deepen the restaurant's financial woes, increasing the risk Michael will be forced to declare bankruptcy, close down his restaurant and give up on his dream. It is a safe assumption that Michael, like other small business owners, will do everything in his power to avoid such a calamitous result. Thus at the risk of this severe sanction, small company owners realize that they must be able and willing to objectively judge their own performance. Together, the desire for rewards and the aversion to sanctions provide the driving force for entrepreneurial

leaders. But is this system of rewards and sanctions present within the education industry guiding the production of education?

The principal is the leader of a school. She is hired by a governing body, be that a district or a school board, to oversee the production of education at the school. As school principal, she is responsible for the quality of the learning environment including the upkeep of the school facility, the supply of educational materials, and the staffing of teachers. She, like Michael Rudolph, needs to carefully analyze her production costs. Her customers are the parents and community members who expect the school to provide their youth with a quality education. And like the customers of the restaurant, they have limits on how much they are willing to pay for that quality. The school principal must find a way to provide the level of quality demanded within the financial constraints established by the community.

For the purposes of this section, assume the production goal of the school is to maximize math and reading test scores, although the logical argument applies to any production goal a school may have. Assume test scores are therefore the measure of quality used to assess the principal's job performance. If test scores are at levels deemed satisfactory by the governing body, the principal is judged to have performed well. However, if test scores fail to meet expectations, the principal's job performance is criticized.

Certainly the principal's performance is driven by the rewards and sanctions; however, economists tend to view their motivational effects as less than those present within private industry. For example, monetary rewards (i.e., pecuniary or extrinsic) are not as great for principals as they are for CEOs. How many principals do you know who earn six-digit salaries? And stock options do not exist for principals.

A common retort to this economic reasoning is that principals do not need extrinsic rewards, but instead are motivated by the intrinsic rewards (i.e., non-pecuniary) associated with a job well-done. For example, the sense of satisfaction a principal receives from knowing that the students at her school are being taught the skills and provided the knowledge they need to be successful in their future endeavors. This sense of satisfaction does not have a specific financial compensation associated with it, but the desire to experience that satisfaction drives her to keep the school safe for the children and to make sure each classroom is staffed by a caring, knowledgeable and talented teacher. With respect to sanctions, principals can be demoted or fired same as leaders in private industry can. Yet given that the rewards for good performance are less, the threat of having these rewards withheld is also less.

A key to being a successful leader, be that of a restaurant or a school, is making the right decisions. Therefore, economic production theory assumes that in order for a firm's leader to be held accountable for the firm's successes and failures, the leader must have **decision-making authority** and those within the firm must acknowledge that authority. The leader can override any decision made by other employees of the firm. Once a decision is made, others at the firm work diligently to carry it out. This decision-making authority extends over the entire production process including the selection of inputs. We will expand on this point in the next sections. Yet, it should be clear that there are significant differences in the decision-making authority given to leaders in private industry and that given to school principals.

In private industry, decision-making authority tends to be centralized in one person, or a very small group of individuals. For example, at *Understated Excellence*, Michael is the sole decision maker. He decides which items go on the menu, how much to charge customers, when the restaurant will be open, how many wait staff will work each shift, etc. At large firms, there may be an executive board headed by a CEO who together make decisions regarding the

production process. The centralized nature of the decision-making authority also enables the firm to meet its production goal. The likelihood of conflicting decisions is reduced when all decisions are made by the same individual or group. This provides leaders considerable flexibility in the decisions they make as long as they remain within the confines of the law. They do not need to predict or second guess the decisions others could make and worry about how they may undermine their own decisions.

Decision-making authority tends to be more diffused and decentralized within the education industry. Multiple groups and individuals have decision-making authority over specific aspects of the production of education, increasing the likelihood that a decision made by one individual will directly conflict with another made by someone else. These decision-makers include the national ministry of education and local government, local school boards, district officials, and the school principal.

To illustrate this point, assume that the school principal decides that in order for students to meet the performance expectations of the community they need to spend more time being instructed in mathematics and reading. One option would be to increase the number of school days. However, that decision is made by the national ministry of education. Another option is to make more efficient use of the time students are in school by requiring students to spend an hour each day studying mathematics and reading. However, spending more time on these two subjects reduces the time available for other subjects. This could conflict with directives from the local curriculum director that schools teach specialized curricula on subjects such as dental hygiene or substance abuse. There may not be enough time in the day to dedicate an hour each to mathematics and reading. You can see that the decentralized nature of decision-making can restrict a principal's ability to lead the school and the school's ability to meet its production goal.

2.2.2.1 Activities for this Sub-Section

1. What is the basis economists use for judging the performance of a firm's leader?
2. What influences a firm's leader to direct a firm toward the achievement of it production goal? How is this influence similar and different between firms and schools?
3. How is the decision-making authority different in private industry and in schools?

2.2.2 Control Over the Production Process

Intimately related to the issue of who possesses the decision-making authority is the issue of how much of the production process the authority encompasses. Is it broad enough to span the entire production process or is it more narrowly targeted? Economic production theory posits that leaders with broader and deeper decision-making authority are better positioned to successfully guide their firm to the achievement of their production goal.

The breadth of a leader's decision-making authority is directly related to the degree to which the production process is centralized. The more dispersed the process, whether that be spatial or temporal dispersion, the weaker the ability of the leader to influence the quality of the output. For this reason, economic production theory assumes that a leader has control over the production process.

In the traditional example of a productive firm, all the productive processes occur within one building or factory. This facilitates oversight and control of the process. Production occurs only when the factory is open. If there are no workers within the factory's walls, no goods are produced. Such a production set-up facilitates quality control. When a product is determined to

be flawed, the firm can trace through the production process to find the cause of the flaw. It can then fashion and implement a solution. Consequently, a highly centralized production process is positively related to the firm's likelihood of achieving its goal—the more centralized, the higher the likelihood.

Understated Excellence fits within this traditional model rather nicely. All the meals are produced within the walls of the restaurant awarding Michael Rudolph the ability to maintain a high degree of quality control. Michael sets the terms of production such as when workers are to be at the restaurant, what meals are prepared, and how those meals are prepared. If customer feedback alerts him to a breakdown in quality, Michael can trace through the process his staff followed to prepare the meal. He is then able to determine what changes need to be made to improve quality. The solution may be on the simple side such as adding more spices or increasing the amount of time in the oven. It might be something more drastic like replacing staff. All these options are available to Michael due to the centralized nature of the production process and his broad decision-making authority. Consequently, he is well equipped to maximize the restaurant's profits and realize his dream of growing his business. A school principal faces more challenges.

The dispersed nature of the education production process makes it much more difficult for a school principal to exert quality control. Unlike the restaurant where meals are only produced when the restaurant is open, the education production process is not confined to the seven hours students spend at school five days a week nine months of the year. It is not the case that students somehow close their brains to learning after they leave the school building. Rather, the production of education continues. The rest of the time parents and the broader community are supervising and directing the education production process. The school has very little to no control over this aspect of production. Yet, the production that occurs outside the school's purview directly impacts the quality of the production within the school and makes it difficult to attribute student learning to processes that occur at the school.

The connection between a student's academic performance and their living situation outside of school is well established in the EPF literature. Family socioeconomic status indicators such as family income, parental education attainment, and number of books in the home, are frequently shown to be factors in explaining why some students perform better than others. The very fact that schools assign homework reveals their belief that the production of education is not limited to the school building. Schools expect students to continue learning when not at school.

Quality control is thus very difficult to enforce in such an environment. Production is not as clearly delineated as in the firm. This makes locating the source of the quality breakdown more of a challenge. At the restaurant, the ingredients are selected and purchased. When they arrive at the restaurant, they are stored until needed by the kitchen staff. Once a customer places an order, the sous-chef gathers the necessary ingredients and prepares them for the chef who combines them into the final meal. Next a member of the wait staff delivers the meal to the customer. With respect to education, students not only move around their community (e.g., home, school, etc.), but they also can move among schools.

Were a school principal to undertake the effort of determining which stage of the education production process caused a specific student's poor test performance, she would surely be in for a huge challenge. Where does the process begin? Does it start when children begin formal schooling? Or does it begin earlier, maybe when children are first born? Given the dispersed nature of the production process, it will be very difficult for the principal to determine

how all the players in the process are related, something that she must do if she is to craft and implement a plan to correct the quality flaw.

And because the school does not control the entire production process, devising and implementing a solution may not even be possible. For example, assume the principal determined that the student was not receiving sufficient attention at home. The principal believes that the student's test performance would improve if his parents read to him more. However, the principal can only recommend this course of action to the parents. The principal's decision-making authority does not apply to aspects of the education production process that occur within students' homes. Consequently, principals must focus their quality control efforts on the production that occurs within the confines of their school. This serves to restrict their ability to lead their school toward the achievement of its production goal.

2.2.2.1 Activities for this Sub-Section

1. What do we mean when we say the breadth of decision-making authority?
2. Who has more control of the production process—a CEO of a firm or a principal of a school? Explain.
3. Is quality control easier in private industry or the education industry? Why?

2.2.3 Selection of Inputs and Outputs

Economic production theory places particular importance on the ability of leaders to select which inputs to use in the production of which outputs. The assumption that leaders have decision-making authority over the production process stresses that they use this authority to properly select the inputs and outputs that enable their firm to achieve its production goal. This requires that leaders identify and select the **optimal production plan**.

Essentially, a production plan is a recipe that explains how a firm can produce some set of outputs, be that one output or more. It tells the firm the quantity of the outputs that can be produced using specific quantities of each input. The general form for a **production plan** is:

(EQ. 1) $$Plan_1 = (output_1, output_2, \ldots, output_M, input_1, input_2, input_3, \ldots, input_N)$$

This plan includes M outputs and N inputs, where both M and N are some positive non-zero number. Specifically, this plan indicates how much of each of the N inputs are required to produce some quantity of each of the M outputs. Notice that this plan has a subscript 1. There are multiple product plans for any given set of outputs and any given set of inputs.

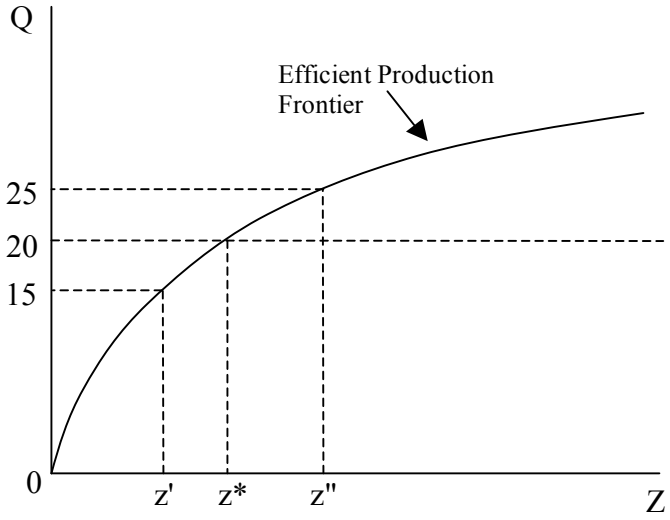
Consider a production plan Michael Rudolph could use to produce one Monday night's dinner to help make this concept more concrete. For simplicity, let's assume that the only meal available at *Understated Excellence* on Monday nights is a filet mignon dinner. The production plans from which Michael will need to choose will have only one output—filet mignon dinners. Based on market demand analyses he had conducted, Michael knows that on an average Monday night there are 20 orders for filet mignon. Preparing these twenty orders requires inputs such as the ingredients for the meal, people to prepare, cook and serve the meals, plates and silverware for the customers to eat the meal, and dining chairs and tables.

Michael must select one production plan from the multiple production plans available to him. One plan for the Monday night filet mignon includes directions that Michael order 30 portions of meat from the butcher and have one individual prepare, cook and serve the meals. Another plan states that Michael should purchase a whole cow and slaughter it himself. The

production plans can vary widely on each input. Clearly some production plans are more **efficient** than others. The most efficient plan is the one in which all the productive capabilities of each input are maximized and waste is minimized. It is up to the leader to determine which production plan most efficiently meets the firm's production goal.

The optimal production plan is the most efficient plan. Figure 1 graphically represents the set of optimal production plans for a specific firm producing one output.

FIGURE 1: Efficient Production Frontier



The vertical axis indicates the quantity (Q) of the output to be produced. The horizontal axis represents how much of the inputs (Z) are needed. (Assume that all the inputs included in these production plans have been combined into one number and that number is indexed on the horizontal axis.)

The arched line is called the **efficient production frontier**. It represents the most efficient production plans available to the firm. Each point below this frontier is a feasible production plan available to the firm. Points above the frontier are production plans not available to the firm. Why is this? Recall that the most efficient plans are those that maximize the productive capabilities of the inputs. Therefore, given some quantity of inputs, the frontier is the largest quantity of output the firm can possibly produce. In order to increase production, the firm must use more inputs, meaning they must move to the right along the horizontal axis.

What is the optimal production plan for Monday night's filet mignon at *Understated Excellence*? As previously stated Michael knows that he needs to produce 20 filet mignon dinners and must select the optimal production plan. If he has this graph, he would draw a horizontal line at 20 on the vertical axis. This line represents all the production plans that can produce 20 filet mignon meals. From this graph he sees that using input combination z^* most efficiently produces the meals.

Why is z^* the most efficient production plan? Consider input sets to the left and to the right of z^*. If Michael selected plans to the left, say z', he would not be able to produce the required twenty filet mignon meals. He can only produce 15 dinners maximum with input set z'. This fails to meet consumer demand of 20 meals.

What about input sets to the right of z^*? Michael can meet consumer demand with these production plans. However, if he selected one of these plans, he would waste productive capacity. Consider the input set z'. At its most productive, this input set can produce 25 meals. Yet, Michael knows that he will only sell 20 meals meaning that 5 meals will go to waste. If Michael is to achieve his dream of expanding his business into new markets, he must maximize his profits. By adopting a production plan that uses the z' combination of inputs to produce only twenty meals, he needlessly incurs additional production costs that he can not offset by increased sales. Consequently, Michael will adjust the amount of inputs he uses down to z^* where costs are minimized given that he must produce twenty filet mignon meals.

It is rare that a leader of a firm has this graph in front of her when she is selecting a production plan. However, the actions firms take in reality resemble the process discussed above. They are constantly looking for means to get more out of their inputs meaning they move toward the efficient production frontier. This requires that firms be free to choose among all the various combinations of inputs. Without this freedom, firms would not be able to adjust their production processes in order to adopt the optimal production plan and thus achieve their production goal.

With the expansion of the global marketplace, the set of inputs from which firms can select has increased. No longer must firms depend on local or national markets to supply all the inputs they need for their production. For example, as additional global markets open up, Michael has access to their produce, spices, sauces, and equipment. Some of these products will replace what Michael currently uses in his restaurant, say if they are cheaper and of better quality. Others will be inputs to which Michael previously had no access. By purchasing these new products, he can develop new menu items to attract new customers. Consequently, economic production theory predicts that with a broader marketplace, firms should be able to be more efficient in their production plans and be better positioned to achieve their production goal.

Firms, of course, do not have full flexibility in the inputs they consume or the outputs they produce. Regulations place restrictions on the production plans from which they can choose. Most firms are required to abide by certain safety regulations. At *Understated Excellence*, Michael is required to keep his meat and produce in separate freezers. Each food preparation station must be equipped with specific safety equipment. These regulations place restrictions on the production plans from which firms can choose. A firm's plan must include these inputs. The firm could elect to have more of these inputs, but it is forbidden by law from consuming less. Although such restrictions may pose barriers to a firm's efforts to find the optimal production plan, regulations can also benefit production. For example, a safer working environment means fewer workplace injuries and workers miss less work as they do not need to take time off to recuperate. Therefore, regulations can help increase worker productivity and efficiency.

Schools do not have the same flexibility as firms in selecting which production plan to use. This is a direct consequence of the fact they do not control the entire production process. Recall, a leader can only apply her decision-making authority to alter the school's consumption of the inputs and the production of the output over which it exerts control. For all other inputs and outputs, schools must accept the production decisions made by others and make their decisions around those of others.

Consider the example given earlier of the school principal who feels her school can most efficiently meet its production goal by having students spend more time in school. This, she believes, will provide teachers with more time to cover material and for students to practice under the guidance of the teachers. The principal feels that students should have 20 more school days each year. However, this is an input outside the purview of her decision-making authority.

A governing agency has already decided the length of the school year. As a result, the principal can not select any production plan that contains more or less school days than determined by the governing agency.

In fact, many of the most important inputs to education are outside the purview of the principal's decision-making authority. Students, the most central input to education, are a perfect example. Most publicly-funded schools can not select which students attend their school. Instead, they are required by law to admit all students within a geographically defined service area. The other resources available to a school—such as teachers and instructional materials—may be best suited to a certain kind of student. Thus, the school's education production process would be most efficient if it only served that certain kind of student. This is a main argument for school choice programs.

Schools are not only restricted in their selection of production plans but also in their inability to charge different rates for different levels of educational quality. At *Understated Excellence*, the menus offer meals at a variety of price levels. For those willing to pay substantial sums of money for a meal, the menu offers the tastiest delicacies and the finest wines. The menu includes other items for those who want a high quality meal but at a more reasonable price. Price differentiation is not a possibility for many schools. They can not approach parents and ask, "What quality of education do you demand for your child? We have three options available—low, medium, and high quality. Our prices increase with quality." Instead, all families pay the same price regardless of how much quality they consume.

However, the quality of education received by different students within a school may vary even though they all 'paid' the same price. Some teachers are better than others. Some students are smarter than others. School policies, such as ability tracking, may implicitly serve students a quality of education that the school thinks their parents demand or that the students' "deserve". The inability to charge different rates restricts the school's ability to purchase a variety of inputs to best educate the array of students it must serve.

We discussed how the expanding global marketplace can benefit the production processes of private firms. Is the education production process similarly benefited? Mostly likely it is not. A comparison of the markets for the two central inputs for a school—students and teachers—to those at *Understated Excellence*—the ingredients and the cooking staff reveals the input markets for education to be much more localized. Assume there are no legal barriers to importing these inputs such as taxes, tariffs or embargos. We thus restrict our comparisons to the efficiency effects of the inputs purchased in the global marketplace.

Accepting students and hiring teachers from other countries could be a highly inefficient decision for schools. Can they speak the same language? If they can not, the language barrier will present significant hurdles to the production of education resulting in lower academic performance than if there were no language barriers. With respect to students from other countries, where will they live? Will the school need to construct dormitories or recruit local families to host foreign students? This may not be the most efficient use of the school's scarce resources. A school's optimal production plan may be to accept students and hire teachers from the local marketplace.

Private industry does not necessarily face these production inefficiencies when using inputs purchased from the global marketplace. Assuming that the domestic and imported ingredients are of the same quality, Michael Rudolph will be able to make the same meal with either ingredient. This is not true for teachers assuming they speak a different language than their students. Two teachers, one from the local area and another from a different country, may be of

the same quality, but their teaching styles and approach to the subject matter could be very different. The education they produce may therefore not be of the same quality. Also, if one goal of the school is to socialize students to cultural norms and behaviors, the imported teachers may not be as familiar with these.

Language barriers, however, need not make all human inputs less efficient. Assume two cooks have received the same culinary training. Each could produce the same quality meals given that the other inputs they interact with are mostly inanimate (i.e., the ingredients, kitchen equipment). True, a foreign cook may have difficulties communicating with other restaurant staff, but it may be possible to automate many of the day to day restaurant activities so that the need for verbal interaction is reduced. Such automation is unlikely to improve the productive efficiency of a teacher who can not communicate with his students.

Similar to private industry, schools face regulations that restrict the selection of inputs and the outputs they produce. For example, many governing agencies require students to complete a specific number of credits in math, language, and science. Schools must hire licensed certified teachers. In other jurisdictions, class sizes must not exceed a given size. These regulations place restrictions on which production plans a school can follow. It is impossible to make a blanket statement on how these regulations influence the efficiency with which education is produced. Some regulations may force some schools to consume more of a specific input than needed, thus causing waste. However, regulations can increase efficiency if they prevent schools from selecting inefficient production plans.

2.2.3.1 Activities for this Sub-Section

1. List two production plans for a school. Each plan should have a different output and include at least 5 different inputs. (Note: These will not be complete production plans. Schools surely use more than five inputs to produce any educational output.)
2. What is the defining characteristic of an optimal production plan?
3. Do firms in private industry or schools in the education industry have more control over the selection of inputs and outputs? Explain.

2.3 Competitive Markets

In the previous section on organizational structure, we examined several key assumptions of economic production theory which enable the firm to meet its production goal. By controlling the production process and selecting which inputs to use and which outputs to produce, an entrepreneurial leader can use her decision-making authority to do what is best for the firm, namely achieve its production goal. Of course, there is a tension here. What may be best for the firm may not be best for the consumer and vice versa. The assumption of competitive markets seeks to even out this tension.

Even if you have never taken an economics course before, you most assuredly have heard references to competitive markets. Competitive markets are frequently credited with keeping prices low and increasing productivity. Economic production theory assumes firms face competition from other firms in both the **input and output markets**. Implications for production in private industry and education are explored in this section.

Competitive markets are the antithesis of **monopolist markets**. In a monopolist marketplace, there is one firm. It is the only firm that produces some given output. Any consumer wishing to buy this output must purchase it from this firm. Without a competitor firm,

the monopolist firm faces little incentive to reduce price or improve quality. Given demand for its product, the monopolist firm will be able to sell the product at whatever price it chooses. This is because there is no other firm selling the same product which can charge a lower price than the monopolist firm and lure away its customers. The lower price could be made possible by firms reducing their production costs and passing those savings along to the customer. Given the steady demand for the product, the monopolist firm does not necessarily need to worry about improving the quality of its product in order to maintain customers. In a competitive market, all firms would be looking for means to improve their product's quality and attract a larger share of the consumer market. It is for this reason that we frequently credit competitive markets as the source for innovations in product design and productive technology. In competitive markets, firms are always searching for a competitive edge that will increase their sales and profits.

There are three key aspects to competitive markets. Firms compete with each other for access to productive goods in the input markets. Firms compete with each other for customers in the output markets. And there are no barriers to entry and exit in any firm.

2.3.1 Input Market Competition

As previously stated, competition acts as a price control mechanism. Each firm has an incentive to charge a lower price than its competitors in order to claim a larger share of the market and increase its revenue. Competition prevents any one firm from naming its own price. First consider the role of competition in the input market for one of the inputs Michael uses in his restaurant. Imagine that *Understated Excellence* was the only business that purchased baguettes. Michael's restaurant is said to have monopoly power in the input market for baguettes.

If the producers of baguettes want to sell any product, they must sell to *Understated Excellence* and will sell to the restaurant at a price Michael Rudolph names. The price must however cover the bakeries' costs otherwise the bakeries would lose money. Eventually they would be forced to close meaning Michael would have no access to baguettes. However, assume that Michael's optimal production plan includes baguettes. Therefore, in order for Michael to meet his production goal, he must purchase the baguettes at a price at least equal to the bakeries' production costs.

2.3.2 Output Market Competition

Turning to competition in output markets, assume *Understated Excellence* is the only restaurant within a 50 mile radius to serve toasted baguettes, which for some reason are in high demand. If customers are to satiate their craving for toasted baguette, they must purchase them from *Understated Excellence*. Michael can therefore charge his toasted baguette craving customers a price far in excess of his production costs. This is because he knows that the customers just have to have the toasted baguettes and he is the only restaurant to serve them.

But now imagine several new restaurants specializing in toasted baguettes open within a few miles of *Understated Excellence*. The restaurants must now compete with each other for the customers' business. In order to win market share, the restaurants will seek to differentiate their toasted baguettes from those of their competitors. Quality and price are their main means of differentiation. In both forms of competition (quality and price), the consumers are better off in that they are getting a higher quality product and/or are paying a lower price.

2.3.3 Barriers to Entry and Exit

When firms are considering whether or not to enter a particular market, they always want to know about the profit potential. Firms are assumed to chase profits. The absence of **barriers to entry and exit** is therefore essential. Recall why Michael entered the restaurant business in the first place; he saw there were profits to be made. Once he entered the marketplace, consumers benefited from the increased competition through lower prices and/or higher quality. If there were barriers to entry, the existing restaurants could charge higher prices for lower quality meals than they would if facing increased competition from Michael's restaurant. Consequently, consumers would be worse off.

Starting or expanding any business carries a certain element of risk. Although Michael intends to earn enough profits to enable him to expand his business, he is aware that there is a chance of failure. He knows that he can cut his loses by closing down his restaurant if he is unable to turn a profit. If barriers to exit exist, Michael would be forced to continue operations, all the time adding to his losses and debt. Michael may therefore not have been willing to undertake this risk and would never have opened *Understated Excellence*. Again, a decrease in competition tends to increase prices and weaken incentives for quality improvements and innovations, making consumers worse off.

Critics of publicly-funded schools often refer to the monopolistic power these schools wield in the market. As a result of their monopolistic power, the cost the public must pay to operate the schools is too high and the quality of the education produced is too low. They argue that school choice programs would create a marketplace for schools in which schools would need to compete with each other for students and the funding that comes with them. Prices would fall, quality would increase, and consumers would be better off.

These are substantial claims. But how accurate are they? Technically, schools are not monopolies. They face competition in both the input and output markets. However it is true that the magnitude of this competition is lower than that in many private sector industries and lower than supporters of school choice want to create.

Consider the competition schools face in the input markets for students and teachers, their two main inputs. As mentioned previously, most students are assigned to schools based on where they live rather than schools competing with other schools for students. However, while there may not be competition among publicly-funded schools for students, there is competition between public and private schools for students. This competition tends to be narrow in scope with the schools competing for the most academically able students and those from families with the resources to afford a private education. Hence, while schools face competition in the input market for students, it is not as broad-based as it is in the input market for teachers.

Schools face competition for teachers. Sometimes this competition is so great that schools have difficulty attracting competent teachers. A teacher's skills and knowledge can be applied productively in many firms other than schools. A writing teacher can be employed as a copy editor for a publishing firm. A physical education teacher could work for a community's recreation department. Numerous firms have demand for the skills and knowledge of math and science teachers. Somehow schools must find the means of competing with these other firms if they are to place a high quality teacher in every classroom. This issue is discussed in greater detail in Chapter 4.

The product schools take to the output market to sell is the quality of the education they provide to students. Who consumes this education? It is appropriate to conceptualize families, not the students themselves, as the consumers of education. Families determine where to reside which for many determines which school their children attend. Families also assess whether or

not they can afford to pay tuition costs at private schools. If families do not value the education a school provides, they will either choose to live elsewhere or send their children to a private school. In this sense, there is a degree of competition in the output market for education.

Economists also view post-secondary educational institutions and business as consumers of education. If institutions of higher education view the quality of education provided by a certain school as substandard, they will be hesitant to admit its graduates. Low college enrollment rates, in turn, become a quality measure on which families select residential locations and whether to send their children to private schools. Businesses demand workers who possess a specific set of skill and knowledge. If students graduate with substandard skills and knowledge, businesses will be hesitant to hire them. Or if they do hire them, the firms will have to spend money and other resources to provide these students with appropriate training, thus increasing their costs of production. Either way, businesses have an incentive not to consume poor quality education (embodied by a school's graduates) and thus will hire graduates of higher quality schools. Poor career placement and trajectories of a school's graduates also factor into a family's education consumption decisions.

There are several barriers for schools to enter and exit the education industry. Profits in education are generally very little to non-existent making the creation of new schools unlikely. Also public funding for the construction of new schools is limited. With regard to exit, schools are integral parts of communities. Even when dwindling enrollments may prove school closure to be appropriate economically, communities are willing to wage fierce fights to prevent their schools from closing. Exit from the industry is often therefore politically infeasible. Compulsory attendance laws pose another barrier to exit. If a school closes, those students must be placed in other schools which may not have the physical capacity to accommodate them.

This discussion argues that schools do face a degree of competition in both input and output markets, but that there are significant barriers to entry into and exit from the educational industry. Given these conditions, economic production theory would predict that the cost of education is higher than it ought to be, quality below what it ought to be, and the speed of innovation and technological advance slower than it could be. Such predictions can be tested statistically with the education production function to which we now turn our attention.

2.3.4 Activities for this Sub-Section

1. What are the three main characteristics of competitive markets?
2. How do consumers benefit from competitive markets?
3. Explain the barriers to enter and exit that are present in the education industry.

3 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.

The diagram below is the basic conceptual framework for every EPF. A **conceptual framework** is any heuristic that represents a social phenomenon. Conceptual frameworks can take several forms. This diagram is an example of a path model.

FIGURE 2: A Conceptual Framework for the Education Production Process

This framework indicates that inputs are fed into the production process. The production process then spits out the output. Notice the boxes around the inputs and outputs are solid while the oval around the production process is dashed. This formatting signifies that the conceptual framework is silent with regard to how the inputs are combined during the production process in order to produce the output. It assumes that schools have used their decision-making authority to select the input set that most efficiently produces the desired output. The statistical model accompanying this conceptual framework can test this assumption.

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.

(EQ. 2) $Y = a + b \times X_1 + c \times X_2 + d \times X_3 + \ldots + U$

There are four components of this and all statistical models: a dependent variable, independent variables, parameters, and an error term. 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).

Each EPF also includes an **error term** (U) that technically is a statistical artifact. This represents all the unobserved determinants of Y. For example, assume Y represents high school graduation rates. What are the determinants (or the Xs, or the independent variables) that predict whether or not a student will graduate? There will be some determinants that can be observed and measured. Because these variables (such as parental educational attainment, grades, and attendance rates) can be measured, data can be collected on students and used in the EPF. However, there are other determinants that can not be easily observed or measured. The classic example is student motivation. More motivated students are more likely to graduate from high school. But how can we measure motivation?

Parameters are the final model component. These are all the lowercase letters in the equation above. Unlike the dependent and independent variables, the values of the parameters are not directly observed by the economist. Instead, the economist must first collect data on all the variables specified in his model and then conduct the statistical analysis in order to estimate the parameters. Parameters indicate how varying the quantity of one of the inputs changes the quantity of the output. As an example, assume that the independent variable X_1 represents the average daily attendance rate at a school and that the statistical analysis estimates the value of the parameter 'b' as +0.5. This suggests that as a school increases its daily attendance rate by 1 percentage point its graduation rate would increase by half a percentage point. There will be more on how to interpret the results of an EPF later in this section.

Before an EPF can be estimated using a statistical software package, of which there are many available, data must be collected. And before data can be collected, the researcher needs to know what to collect. This means he must first specify both the inputs and outputs of his model. We examine these issues next.

3.0.1 Activities for this Sub-Section

1. Define the four components of an EPF.
2. Can you collect data on the error term and use it in the estimation of an EPF? What about the parameters?

3.1 Choosing an Output and the Inputs

The output included in an EPF should relate to the school's production goal. Recall that a key assumption of economic production theory is that firms set a production goal and direct all their productive energies towards its achievement. An EPF is meant to model this production process. If an economist chose an output unrelated to the firm's production goal, the EPF would fail to capture the firm's production process. The results would be said to have low **validity** meaning they do not sufficiently represent the social phenomenon being analyzed.

Choosing an output involves three basic steps. First, identify the school's production goal. The production goal will determine the output used in the EPF. Second, identify the data best representing that production goal. Third, determine what data is available and examine how it represents the production goal.

Identifying a school's production goal is complicated by the distribution of decision-making authority over the education production process. As discussed previously, this authority is not centralized in one individual such as the school principal. Rather, there are multiple individuals who possess decision-making authority over specific aspects of the process. This decentralization typically results in multiple production goals. Which goal should the economist model in his EPF? The economist may find that one goal receives more attention from school leaders and staff than others. Using this goal as the output in the EPF may afford the economist the best opportunity to model the school's production process. Alternatively, if no production goal dominates the others, the economist's best course of action would be to model multiple EPFs—one for each production goal. By choosing only one goal, the economist may fail to accurately represent the education production process.

Having identified the school's output (i.e., 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.

It may be the case that complete data is not available on the output most closely related to the school's production goal. Again, assume the school's production goal is to maximize the academic achievement of all its students in the four grade levels served by the school. However,

the only test scores available are mathematics test scores for two of the four grade levels and reading test scores for the other two grades. If the economist decides to use the mathematics scores, are the EPF results applicable to the production of reading test scores? Are the EPF results for the production of mathematics test scores in the two grades analyzed applicable to the production of mathematics test scores in the other two grade levels for which data is unavailable? In other words, does the school use the same inputs in the same quantities to maximize mathematics test scores as it uses to maximize reading test scores? Answers to these questions will depend on the assumptions the economist makes about the school's education production process. These assumptions are frequently the source of disagreements among researchers on the validity of any EPF result.

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. Schools, however, do not have the flexibility to select all of their inputs. Therefore the inputs included in the EPF must be both those over which the school has decision-making authority as well those inputs determined by other decision-makers.

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. The divisions between these categories, however, are not impermeable. One economist may view a specific input as a characteristic of the community, while another will

include it as a school input. Depending on how the production goal and the production process are conceptualized, both may be correct.

As you can imagine, not all inputs and outputs are easily measured. Consider principal leadership and the quality of teacher instruction. What exactly do we mean by principal leadership or instructional quality? What do we expect principals and teachers to do? What do we consider strong, moderate, and weak leadership? What characterizes high, average, and low instructional quality? Assuming we can answer these questions, it is possible to measure these inputs through surveys or classroom observations. An example is a survey of teachers' their impressions of how well their principal performs in the various aspects of the job. However, data on some inputs is just not feasible to collect. Consider the student's home environment. To collect data on this input could require someone to visit the home of every student in a school. Such an exercise would be very timely and costly. Economists, when designing their EPF, must balance their beliefs about a school's production process and data availability.

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.

Consider the following two examples. An economist wants to examine how differences in per pupil expenditures are related to differences in high school graduation rates between schools. She believes that students are more likely to graduate from schools that spend more money than schools that spend less. Now assume that all the schools in his sample have graduation rates of 85 percent. Because there is no variability in the output (high school graduation rates), the economist can make no statements about the relationship between per pupil spending (the input) and graduate rates (the output). This is because the data shows that the students in a school with expenditures of €1 per pupil are just as likely to graduate as students in a school with expenditures of €7,000 per pupil.

Another 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.

It is generally not difficult to obtain data with sufficient variability in both the dependent and independent variables. There are very simple statistical tests to check for sufficient variability.

3.1.1 Activities for this Sub-Section

1. The local municipal government has hired you to evaluate the degree to which their schools are achieving their mission. The schools' mission statement is "to provide all students with a quality education that provides them with the skills required for success later in life." You decide to estimate an EPF in order to assess how successful the schools are at achieving this mission. The data they provide includes the following outputs for each student enrolled in the

schools: 1) each student's attendance record, 2) the satisfaction of each student's parents with the quality of education the student receives, and 3) each student's score on end-of-year standardized tests in reading and mathematics. Which output, if any, would you include in your EPF? Why? Be sure to address the validity of each output in your explanations.

2. Assume you select the output with the highest validity (in your opinion) from the three possibilities listed in question 1, what inputs should you include in your EPF? List two inputs from each of the three main groups of inputs. Provide a brief explanation why you would chose each input in which you discuss how the variability in the input might be related to variability in the output.

3.2 Multiple Outputs and Multiple Output Measures

As discussed earlier, 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?

Larger schools can increase the likelihood of students becoming nameless faces among a crowd and falling between the cracks. Students in large schools may therefore be more likely to drop out than students in smaller schools. Thus, the production plan, concerned only with this one goal, would direct the school to reduce the size of its student body—the exact opposite instruction from the previous production plan.

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. Assume that an economist is interested in how school size influences the production of education. To be most accurate, she would need to collect data from a large number of schools on student test scores and dropout rates as well as other school and classroom, family and student, and social context inputs. However, it is frequently the case that economists do not have access to all this data. What are the ramifications of missing data on the accuracy of EPF results?

EPF results based only the available output data may or may not apply to the production goals for which there is no data. Imagine that student achievement data were not available for the schools discussed above. An EPF with dropout rates as the output would suggest that smaller schools are more efficient than larger schools in producing education. But should student achievement data have been available and not dropout rates, the economist would have reached the opposite conclusion. Larger schools would have appeared more efficient.

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. Results from an EPF using the available mathematics test scores may not hold true for the production of reading test scores for which data are not available. Mathematics test scores may require a different set of inputs than reading test scores.

Without all the data, economists, like all researchers, rely on theories and other research on the education production process to address concerns arising from missing data. Say only math tests scores were available, but that other research had been conducted that predicted reading test scores using the same set of inputs. If the EPF results from these other studies indicate similar relationships between the inputs and both math and reading test scores, the economist has some evidence to support an argument that the production processes for the two disciplines are similar. She could then claim that should she have had access to reading test scores the EPF results would have been similar to those she found for the production of math test scores.

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.

3.2.1 Activities for this Sub-Section

1. Multiple goals may require different production processes to be achieved. Explain why this is a challenge for economists in designing an EPF.
2. What challenge do multiple measures of a production goal present in designing an EPF?

3.3 Comments on the Statistical Estimation of EPFs

All education production functions are a form of a statistical technique called multivariable regression. **Multivariable regression** is a large group of statistical models where a single dependent variable is regressed on (or predicted by) more than one independent variable. While the details of the estimation theory used by these models are beyond the scope of this chapter, there are two issues that we want to address here: random sample and selection bias.

3.3.1 Random Sample

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. For example, a researcher wants to know how increasing the daily math instruction time from 45 to 60 minutes affects math test scores for fourth graders. The population of interest is all students in the fourth grade. Clearly, it would be impossible for

the researcher to collect data on every fourth grade student. Instead she selects a sample from the population, say the fourth graders in ten schools, on which she will conduct her 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. **Biased** is a statistical term for how closely related the empirical results (i.e., the parameters) from a sample are to the population. A parameter is said to be unbiased if it perfectly represents the population and is biased if it isn't representative. We will leave the topic of proving whether or not a parameter is biased to other textbooks.

Randomized sampling is a sample selection technique designed to reduce sample bias and increase generalizability of results. With randomized sampling, every member of the population has an equal chance of being selected into the sample. This means that no one segment of the population can somehow rig the selection system with the result that their representation in the sample is disproportionate to their representation in the population. For example, if 47 percent of the population is male, males should comprise approximately 47 percent of the sample. Randomization will usually not result in a sample whose characteristics perfectly match the population. There are statistical techniques that can indicate if the sample characteristic is significantly different from the population characteristic. If significant differences exist, the results are more susceptible to bias. For example, EPF results are likely to be biased if based on a random sample with 20 percent male when the population is 47 percent male. However, a random sample with 50 percent male from the same population may produce unbiased results. As a general rule, the risk of biased EPF results decreases as the size of the sample increases.

3.3.2 Selection Bias

Another common form of statistical bias is selection bias. **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. Take the case of an EPF that finds higher test scores in schools with an average class size of 15 students than students in schools with an average class size of 25 students. These efficiency gains may not be a consequence of the smaller class sizes. It could be that the small classes are located in wealthy communities while the large classes are in poor communities. The wealthy communities are able to afford the increases in production costs from hiring more teachers and building more classrooms in order to reduce class sizes. However, it is likely that test scores were already higher in these wealthy communities prior to class size reduction given the fact that students in wealthy communities tend to outperform other students.

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.

3.3.3 Activities for this Sub-Section

1. Assume that 45 percent of the individuals in the population of Spain have brown eyes, 40 percent have blue eyes, and 15 percent have hazel eyes. A random sample of 100 people is drawn from this population. How many people would you expect to have brown eyes, blue eyes, and hazel eyes? Explain your answer.
2. What is selection bias? Focus your answer on how it affects the interpretation of EPF results.

3.4 Interpreting an EPF

We now turn to the interpretation of results from an EPF using as an example results from an analysis of eighth grade mathematics achievement.[1] The authors assume that that the schools included in this study have identified the maximization of math test scores as a production goal. In particular, 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 Third International Mathematics and Science Study (TIMSS). Within each country that participated in TIMSS, random samples of students were selected. Each student sample is intended to be representative of all the students in their country. For example, TIMSS includes 1,273 students in Germany and 3,494 students in the Czech Republic.

For each country, the authors estimate the following EPF:

$$\text{(EQ. 3)} \qquad A = a + (b_1 \times P_1 + \ldots + b_7 \times P_7) + (c_1 \times X_1 + \ldots + c_{18} \times X_{18}) + (d_1 \times S_1 + \ldots + d_6 \times S_6) + U$$

The output A is each eighth grade student's mathematics test score. It is regressed on a group of seven variables (P_1 through P_7) representing characteristics of the students and their families, a group of eighteen variables (X_1 through X_{18}) representing school and classroom inputs, and a group of six social context variables (S_1 through S_6). Recall that the U in the equation is the error term. It is a statistical artifact that represents all the unobserved (and hence unmeasured) inputs in the education production process.

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

Table 2 presents the selected EPF results from two countries, Germany and Korea. These figures are the EPF estimates for some of the parameters in Equation 3 above. Each estimated parameter value represents the change in the students' eighth grade mathematics test score (the output) for a one unit increase in the input. We need to include a few words on how inputs and outputs are measured in the EPF before interpreting specific results,

Inputs and outputs are represented by two types of variables in this analysis – continuous and categorical variables. **Continuous variables** include math test score, student age, number of books in the home, and teacher experience. These variables can take on a range of values representing the quantity in which something is present. The values can be ordered so that higher values indicate larger quantities of the input are present in the production process. However, not all inputs can be measured by the quantities used.

Categorical variables are used to represent inputs that are measured in categories such as gender and school location. People are either male or female. A school is located in either an urban, suburban, or rural area. The key here is that an observation (here a student or a school) can be in no more than one category. For example, a student is either a female or a male, but can not be both. Categorical variables are included in EPFs by converting them to **dummy variables** that take one of two possible values – 0 or 1. These variables are also known as indicator variables since a value of 1 indicates something is true and a value of 0 indicates it is false.

If a categorical variable has k categories (where k is any positive integer value greater than 1), k-1 dummy variables are required to fully represent the input in the EPF. For example, gender has two categories (k = 2). The EPF therefore includes one dummy variable (k–1 = 2-1 = 1), *student female*, to represent this input. It is equal to 1 if the student is a female and equal to 0 if the student is not female. Male students are indicated when *student female* equals 0.

The school input of school location has three categories (k = 3) and therefore the EPF includes two dummy variables for it (k–1 = 3-1 = 2). *Located in city center* is equal to 1 if the school is in an urban area and 0 if it is not. *Located in suburb* is equal to 1 if the school is located in a suburban area and equal to 0 if it is not. Rural schools are those where both the *located in city center* and *located in suburb* dummy variables are equal to 0. If this isn't clear to you, think about what being in a rural area means. A school located in a rural area must meet two conditions: (1) not located in an urban area and (2) not located in a suburban area. All schools satisfying condition 1 have a value of 0 for the *located in city center* dummy variable. And all schools satisfying condition 2 have a value of 0 for the *located in suburb* dummy variable. Since rural schools must meet both conditions, schools with values of 0 for both dummy variables must be located in rural areas.

The interpretation of a specific parameter for a given input requires that all other inputs be held constant, ***ceteris paribus***. Why hold everything else constant? Recall that the parameter indicates how much the output changes when there is an increase of one unit in the input. In order to isolate this effect, we need to hold everything else constant. However it is possible to interpret the effects of changes in more than one variable by adding up the parameters for the variables that are changing. But the interpretation still requires *ceteris paribus* for all other variables. The sum of the parameters is the expect change in math test scores when everything else is held constant.

TABLE 2: 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 Projects (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 groups (c_8)	1.23	0.86
Discuss Homework (c_9)	0.63	-0.81
School 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

3.4.1 Student and Family Characteristics

Achievement differences between male and female students are well studied phenomena in the EPF literature. The value of the b_1 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. But what is this saying about the average math test score for male and female students? An increase from 0 to 1 represents the difference between female and male. The difference in average math test scores between female and male students is b_1. To see this consider the following equation:

(EQ 4) Change in A = $b_1 \times$ (*student female* = 1) – $b_1 \times$ (*student female* = 0)

Change in A is the difference between female test scores and male test scores holding all else constant. Using the parameters from the Germany model, this equation solves to:

(EQ 5) Change in A = (-1.85 × 1) – (-1.85 × 0) = -1.85

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

You can use this same process to interpret the b_6. 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. What is the interpretation for b_6 in Germany?

3.4.2 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. For example, urban schools in the United States are frequently shown to be less efficient than their suburban counterparts. Rural schools in China have been found to be less efficient than schools in urban areas.

What do the results in Table 2 suggest about differences in average mathematics test scores of students in schools located in urban, suburban, and rural areas? To answer this question we focus on two parameters d_5 and d_6. 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 $d_6 - d_5$. To see this, solve the following equation:

(EQ. 6) Change in A = $d_6 \times$ (*located in city center* = 1) – $d_5 \times$ (*located in suburb* = 1)
= $(1.02 \times 1) - (0.56 \times 1) = 0.46$

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

3.4.3 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 c_{10} 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. Each variable is based on a survey question which asked "How often does this happen in your mathematics lessons?" The variables take on values anywhere between 1 and 4. A value of 1 indicates that an activity "never" happened and a value of 4 indicates that it "almost always" happened. Although the individual student responses are a categorical variable (it has four possible values), the authors use a within-school average of individual student responses. The within-school average is a continuous variable that can take on any value between 1 and 4.

Examining the EPF results for the c_3 through c_9 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.

3.4.4 Activities for this Sub-Section

1. What does *ceteris paribus* mean? Explain the role does it play in the interpretation of EPF results.
2. Based on the EPF results in Table 2, what is the gender achievement gap in Korea? Is it larger or smaller than the gender gap in Germany?
3. What is the difference in math test scores between male students with a computer in the home and female students without a computer in the home?

4 COMPARING RESULTS: COST-BENEFIT AND COST-EFFECTIVENESS ANALYSIS

Even a casual perusal of the EPF literature will reveal a large number of programs and policies that have been found to have positive impacts on the education production process. There are EPFs supporting large schools and small schools, curricula stressing basic skills and curricula emphasizing higher order thinking skills, longer school days and school years, and performance-based incentives for teachers, just to name a few. How is a decision-maker to decide which program or policy to implement in schools? How can we compare the results from multiple EPFs in order to determine which program or policy is best suited to help a school meet its production goal?

Cost-effectiveness and cost-benefit analyses are two techniques economists have developed to assist decision-makers in determining which intervention to implement given the school's limited financial and physical resources. The first technique, cost-effectiveness analysis, compares how much each intervention costs in order to produce the same benefit. The idea is to identify which can produce a given benefit for the least cost. The second technique, cost-benefit analysis, compares how much each intervention costs to the monetary value of the benefits each yields. Here the idea is to find which yields the highest benefit for each dollar spent.

To help illustrate the fundamentals of these two techniques, consider the following situation. Assume a school is looking for ways to increase student academic performance. A review of the EPF literature uncovers several studies that find reductions in class size and increases in teacher professional development both lead to higher test scores. Facing a tight budget, the school principal must decide which intervention to implement. He is aware that each program requires him to purchase a specific set of additional inputs. Smaller class sizes at the very least require more teachers and more classrooms. The list for expanded professional development opportunities includes more substitute teachers, fees to bring outside educational consultants to the school, and travel expenses to send teachers elsewhere. The principal turns to the local economist to help him select one program.

4.1 Cost-effectiveness Analysis

Cost-effectiveness analysis requires two things – data on the effects of the intervention and figures on how much the program costs. The data on each intervention's effect on student achievement comes from the EPF analyses. The magnitude of this effect comes from the parameter estimates on the dummy variables indicating whether or not a school has the intervention. Given that most EPF studies do not provide cost information, the economist would

have to collect this information herself. Cost data could come from schools that have implemented the interventions or from cost projections from the school itself.

Once the data is collected, the economist compares costs of the required inputs to the quantity of the output generated by calculating the cost-effectiveness ratio (CER). The CER is simply the cost of a particular program (C) divided by its effectiveness (E = the EPF parameter estimate).

(EQ. 7) $CER = C/E$

A CER is interpreted as how much each unit of effectiveness costs. For example, assume the CER for the class size reduction program was 150. This means that to increase test scores by 1 point schools must spend $150. The program with the lowest CER is the most cost-effective program.

4.2 Cost-benefit Analysis

Cost-benefit analysis is more controversial than cost-effectiveness analysis because it requires that benefits—test scores in this case—be converted to dollars. It compares the financial costs of each intervention to the financial benefits generated. But how are test scores converted to dollar figures? Economists do so by considering the long-term consequences of test scores.

There is a large body of research linking academic achievement to outcomes later in life. High achieving students are more productive workers, less likely to commit crimes, and more likely to live healthy lifestyles. Cost-benefit analysis attaches dollar figures to each of these long-term outcomes. Increased productivity helps grow the economy. Lower crime rates reduce the costs to the legal system and the costs to the victim. Healthier people require less emergency medical care and fewer days off work. Also notice that with fewer people incarcerated and fewer people out of work, more people are able to work which reduces the demand for social services provided by government. This presents another cost savings. A major source of controversy focuses on the ability of cost-benefit analysis to accurately capture social costs and benefits.

Once data on costs and benefits have been collected, they are combined in several ways, commonly through cost-benefit ratios (or benefit-cost ratios) and net present value calculations. Cost-benefit ratios (CBR) are analogous to the CER from above with effectiveness (E) replaced by benefits (B). Programs with the lowest CBR are said to be the best investment.

Net present value calculations are based on the premise that a dollar today is more valuable than a dollar tomorrow. Future benefits are therefore discounted to their present value using a discount rate. This rate is simply a figure that reduces the value of future benefits to their current value. Therefore, a program's net present value is the present value of the benefits minus the present value of the costs. The program with the highest net present value is deemed the best investment.

4.3 Advantages and Disadvantages

Each of these techniques has its advantages and disadvantages. The primary advantage of cost-effectiveness analysis is that it focuses on immediate educational output – test scores or graduation rates. They are therefore easier to measure than their long-term benefits as required by cost-benefit analysis. Effectiveness measures are also less controversial than measures of benefits. Cost-effectiveness analysis has the disadvantage of requiring that intervention effectiveness be measured in the same units. For example, cost-effectiveness analysis can not be

used to compare a program's effectiveness of increasing test scores to another program's effectiveness at increasing graduation rates. This technique provides no means of equating increases in test scores to increases in graduation rates. If the two programs have a CER of 150, is it better to increase test scores by one point or graduation rates by one percentage point? This requirement severely restricts the applicability of cost-effectiveness analysis in the comparison of EPF results.

The major disadvantage of cost-effectiveness analysis is the primary advantage for cost-benefit analysis. Because all costs and benefits are measured in euros, any two interventions can be compared. These do not need to be restricted to educational interventions, but rather include any social intervention. For example, the costs and benefits of an educational intervention can be compared to the costs and benefits of a community health initiative. However, the major disadvantage of cost-benefit analysis is the difficulty in measuring an intervention's long-term benefits and the controversy that generates. Recall the discussion earlier of the difficulty in measuring many essential inputs into the education production process. Those same measurement problems are present in cost-benefit analysis. The benefits of one intervention may be more easily measurable than the benefits for another intervention. Consequently, the results of a cost-benefit analysis would be biased in the favor of the former intervention.

4.4 Activities for this Section

1. How are cost-effectiveness and cost-benefit analyses useful to decision-makers?
2. Explain the ways in which cost-effectiveness and cost-benefit analyses differ.
3. A local schools has hired you go conduct a cost-effectiveness evaluation of three educational interventions they have implemented in their fourth grade classrooms. Each intervention was intended to improve student performance in mathematics. Consider the following fictitious cost and effectiveness data for three interventions. The school has three fourth grade classrooms and each classroom used a different intervention. All fourth grade students were randomly assigned to one of three classes. Recall from section 3.3 that this means that there should be no selection bias within the school as to which type of student received which intervention.

Intervention	**Cost per student**	**Average gain on math test – ALL STUDENTS**	**Average gain on math test – MALES**	**Average gain on math test – FEMALES**
Peer tutors	40	10	7	12
Teacher aide	360	22	18	24
Computer-assisted instruction	120	18	21	15

   a. The school principal tells you that she is under a lot of pressure from parents to increase test scores. Her primary concern is to implement the intervention that produces the increases test scores the most. Which intervention would you recommend she implement in all the school's fourth grade classrooms? Would your recommendation change if she told you that she was willing to have separate math instruction for male and female students if that helped increase test scores? Explain your answer.

b. Now assume that the principal tells you, although she feels pressure to increase student test scores, her budget is extremely tight. She says she will need to justify the costs of the intervention to be implemented in all fourth grade classrooms. From a cost-effectiveness standpoint, which intervention would you recommend? What would you recommend if students were to be separated by gender for math intervention? Explain your answer. Are your recommendations different from those in part a?

SUMMARY

Education is central to the health and prosperity of any community. Concern about the state of education has generated a large body of research literature. The economics of education is a subsection of this literature. Economists have focused their efforts on the education production process. Their research applies classical production theory to the education industry. The education production function is their primary analytic tool for examining how schools can produce higher quality education more efficiently.

We began our discussion with a review of the key assumptions of production theory and their applicability to schools. Firms are assumed to have one clear, well-defined goal that guides the firm's production process. Firms are assumed to have an entrepreneurial leader with decision-making authority. This authority provides the leader with control over the entire production process including the selection of which outputs to produce with which inputs. Finally, firms are assumed to operate in competitive markets where they face competition from other firms in both the input and output markets and there are no barriers to entry and exit.

Applying these assumptions to schools reveals some limitations. Schools frequently have more than one production goal. A school is led by a principal whose actions are guided by a weaker incentive system than a firm's CEO or president. Much of the education production process is outside of the direct control of the principal. Consequently, many production decisions regarding inputs and outputs are made by others and must be implemented by the principal. With respect to competition, schools do face competition. But this competition is of a lesser degree than most firms in private industry. Although these assumptions do not hold perfectly, it is still possible to apply production theory to education.

Economists must be aware of the degree to which these assumptions apply when they design an education production function. They must pick an output that is related to the school's production goals. The input set included in the EPF must encompass both those inputs inside and outside the control of the principal. These limitations to a principal's decision-making authority must be acknowledged in the research questions the economist poses.

We saw how results from an education production function can provide very useful insights into the education production process. These insights can help policy-makers design and implement programs and policy that can help improve the quality of education produced and increase the production process's efficiency. Finally, we reviewed two techniques—cost-effectiveness and cost-benefit analysis—economists have developed to assist policy-makers in their decisions of which intervention to implement.

GLOSSARY

Barriers to entry and exit: a feature of competitive markets where there are no systemic barriers (e.g., exorbitant costs, legal prohibition, etc.) to new firms entering a particular industry and to existing firms from exiting a particular industry

Bias: a statistical concept indicating how dissimilar the estimated parameters from a statistical model based on a sample are from the true parameter based on the population

Categorical variable: a random variable that takes on a countable number of discrete values (e.g., 1, 2, 3, 4, etc.) with each value indicating membership in a specific mutually exclusive categories

Ceteris paribus: Latin for "with other things equal"; an assumption required when interpreting specific parameter estimates from statistical models

Competitive market: a key assumption of classical production theory that posits firms participate in a marketplace where buyers of goods meet suppliers of those goods and that marketplace is defined by competition in the input market, competition in the output market, and no barriers to entry and exit

Conceptual framework: any heuristic used by researchers to depict the social phenomenon under study

Continuous variable: a random variable that can take on a continuum of values which can be ranked such that higher values represent more of the characteristic the variable measures

Cost-benefit analysis: an analytic technique used to compare more than one social intervention based on one of several calculations relating the financial costs of the intervention to the financial benefits it generates

Cost-effectiveness analysis: an analytic technique used to compare more than one social intervention based on one of several calculations relating the financial costs of the intervention to some measure of the intervention's effectiveness

Cost minimization: a production goal according to which the firm selects a quantity of an output to produce and then seeks to product that quantity at the cheapest cost possible

Decision-making authority: a key assumption of classical production theory that posits a firm's leader has the power to personally make any decision or approve or override any decision made by others regarding the production process, thus guiding the firm to achieving its production goal

Dependent variable: the left-hand side variable in a statistical model the variation of which the model is attempting to explain; in an education production function, this is the educational output of the production process being studied

Dummy variable: a special class of categorical variables that only has two values; also known as indicator variables, given a value of 1 indicates membership in a category and a value of 0 indicates non-membership in a category

Education production function: n. a statistical equation that economists use to understand how much of the educational good, or output, can be produced when a specific input set is used in the education production process

Education production process: the process through which student and family inputs, school and classroom inputs, and social context inputs are combined to produce some educational output

Efficiency: a measure of the avoidance of waste; a production process that uses all the productive capacity of the input set (i.e., not capacity is wasted) to produce output is said to be efficient

Efficient production frontier: the set of optimal production plans

Entrepreneurial leader: a key assumption of classical production theory that posits a firm's leader is driven by an incentives system to guide the firm toward the achievement of its production goal

Error term: a statistical artifact of any statistical model that represents all the unobserved determinants of the dependent variable

Generalizable: a characteristic of empirical findings based on analysis of a sample such that they hold true for the entire population from which the sample was drawn

Independent variable: a right-hand side variable in a statistical model that is theorized to explain some of the variation of the model's dependent variable; in an education production function, it is an input into the education production process

Input: any good used in a production process; with respect to the education production process, inputs include student and family inputs, school and classroom inputs, and social context inputs

Input market: with respect to a particular firm, it is the marketplace in which it purchases the inputs it uses in its production process

Input set: the collection of inputs used in a production process

Intervention: any interference such as a policy or program intended to change a social phenomenon

Monopolistic market: an input marketplace where the purchasing firm faces no competition from other firms or an output marketplace where the selling firm faces no competition from other firms

Multivariable regression: a statistical technique in which one dependent variable is regressed on more than one independent variable with the intention of using the variation in the independent variables to explain the variation in the dependent variables

Optimal production plan: the production plan that most efficiently produces a given level of output

Output: the resultant product of a production process

Output market: with respect to a particular firm, it is the marketplace in which the firm sells the output produced by its production process

Parameter: a component of any statistical model indicating how a much change in the dependent variable is caused by a one unit change in an independent variable, ceteris paribus

Population: the group or universe of items from which a sample is drawn and to which the researcher seeks to generalize findings from a sample

Production goal: the intended end result of a production process; a key assumption of classical production theory posits that a firm's production process is guided by one clear and well-defined production goal

Production plan: a guide to the production process that indicates the quantities of each input in the input set that will be used to produce some specific quantity of each output

Profit: the difference between the revenue a firm generates from selling its output and the cost the firm incurred in producing the output

Profit maximization: a production goal according to which a firm selects a quantity of an output to produce that generates the highest level of profit possible given the prices of the inputs used in production and the price customers are willing to pay for the output

Random sample: a sample assembled through randomized sampling such that every item in the population has an equal chance of being selected into the sample in order to reduce bias and increase generalizability of results

Sample: any subset of items from a population

Selection bias: a class of bias arising when members of a sample differ systematically from other members of the population not included in the sample

Variation: a measure of how the values of a variable differ across observations in a sample or population

Validity: a measure of the degree to which results accurately represent a phenomenon as it occurs in a sample

REFERENCES

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

Hanushek, E.A. (1986). "The Economics of Schooling: Production and Efficiency in Public Schools," ***Journal of Economic Literature***, 49(3), pp. 1141-1177.

Levin, H.M. and McEwan, P.J. (2001). *Cost-effectiveness Analysis, 2nd Edition*. Sage Publications, Inc.: Thousand Oaks, CA.

Schiefelbein, E., L. Wolff, y P. Schiefelbein (2000). La opinión de expertos como instrumento para evaluar la inversión en educación primaria. *Revista de la CEPAL, 72*(3): 147-163.