Down on the Farm: Marginal Productivity and Profit Maximization in a Factor Market

Lesson Author

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Lesson Description

In this lesson, students will participate in an interactive simulation to determine the number of workers a farm should hire to maximize profits in a perfectly competitive labor market.

Concepts

Factor cost (resource cost)	Marginal physical product (MPP)	Price
Factor market	Marginal revenue product (MRP)	Profit maximization
Fixed capital	Output	Returns to scale
Labor	Perfectly competitive	Total revenue
Marginal factor cost (MFC)	Physical product	Wage

Objectives

The student will be able to:

- Define all key terms listed in the Concepts section.

- Explain why a firm will hire workers until the marginal revenue product is equal to the marginal factor cost.

- Interpret data to determine the profit-maximizing quantity of labor to hire.

- Interpret data to determine whether the returns to scale are increasing, decreasing, or constant.

Time required

90 minutes

Materials

PowerPoint slides ("How Many Workers Should I Hire?") (https://atlfed.org/3NRsh90)

Visual 1: "Data Charts for Farms 1 and 2" (Display and complete two of these during the lesson.)

Visual 2: "Loans for Farms 1 and 2" (two copies)

Handout 1: "Simulation Record Sheet"

Handout 2: "Marginal Analysis Practice Assessment"
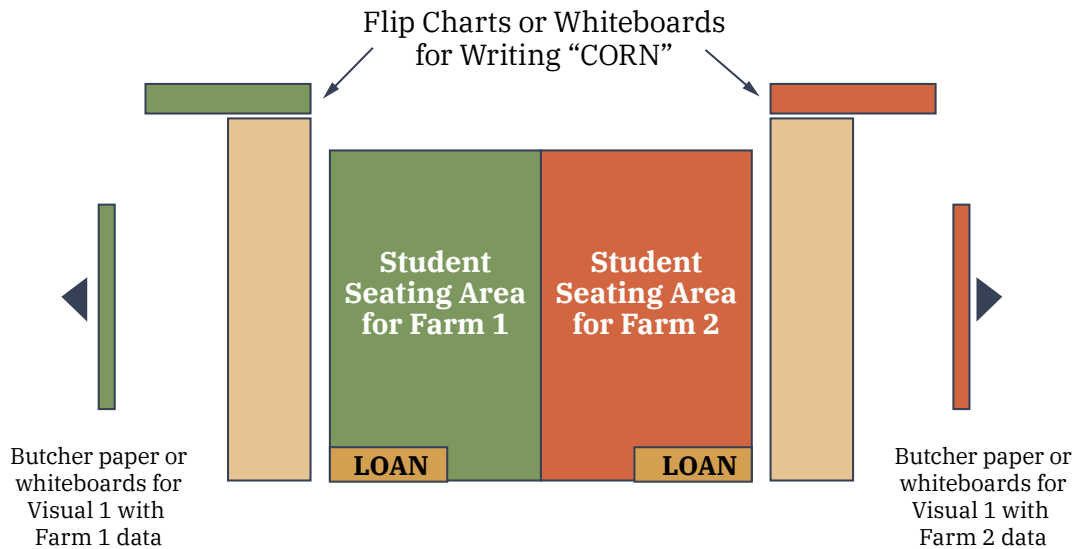
Method for displaying visuals

Markers (at least six)

Stopwatch

Preparation

It is important to get the space set up prior to running the simulation. The diagram below shows how I usually run this simulation in my classroom. It is best to have Visual 1: "Data Charts for Farms 1 and 2" for both farms prepared before class. When I was teaching, I went to a home improvement store and got a big sheet of white-board material cut into poster-size rectangles. I put the charts on a poster so I could use the same chart for each class and simply erase the data.

Flip Charts or Whiteboards
for Writing "CORN"

Student Seating Area for Farm 1

Student Seating Area for Farm 2

LOAN

LOAN

Butcher paper or whiteboards for Visual 1 with Farm 1 data

Butcher paper or whiteboards for Visual 1 with Farm 2 data

Procedures: Instructions for the PowerPoint presentation slides are in *italics* below.

1. *Open the presentation and display slide 1.* Tell students they will participate in a simulation to determine the profit-maximizing quantity of labor to hire in a perfectly competitive labor market. Explain that in a perfectly competitive labor market, firms can hire each worker at the market wage. This type of labor market has many workers with identical skills so the workers lack any wage-setting power. Firms must decide what number of workers will maximize their profits.

2. *Display slide 2.* Tell students they will be producing corn during the simulation.

3. *Display slide 3.* Use this slide to explain the method of "CORN" production. Divide the class in half and designate the halves as farm team 1 and farm team 2. Tell students each farm will have a field (place to write), a seed drill (a marker to write "CORN"), and farmworkers from their team. Explain the field is land, the seed drill is capital, and the farmworkers are labor. Tell them the land and capital are fixed resources, but labor will vary each round. Explain that farms need farmworkers and the farmworkers who will produce the corn are labor resources with identical human capital. To produce "CORN," the first farmworker from each team will come to the field and stand with his or her back to the field. Tell students that farming is expensive and each farm will need to a secure a LOAN to begin planting CORN. The farmworker will do this by walking fast (or running, if permitted) to the back of the room to pick up the paper that says LOAN. As soon as the farm-worker returns to the field, he or she can begin writing the word CORN on the field as many times as possible in the time allowed. CORN must be legible and written in ALL CAPS to count. If possible, demonstrate the process for the students. Tell them each round will be 30 seconds long.

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4. *Display slide 4.* Explain that at the end of each round both farms will make some calculations to help them decide what number of workers to hire. Distribute Handout 1: "Simulation Record Sheet" to each student. Explain that in this simulation the price of each bushel of CORN is $8 and the wage is $5. (Feel free to adapt this if you would like to use values closer to the actual value of these variables. At the time of publication, a bushel of corn was selling for about $3.50 and the median hourly wage of a farmworker was $11.) Tell students to look at the definitions and formulas associated with the key concepts at the top of the page. Click through the explanation of each concept on the chart and discuss each with the students. Tell students the farms will want to hire workers until the MRP = MFC because this is the profit-maximizing quantity of labor. If these values never reach a point where they are equal, the farm will want to hire the last worker where MRP is greater than MFC. Ask if they have questions about how to compute the values.

5. *Display slide 5.* Explain slide 5 shows the setup and jobs for each farm in round 1. Make sure your room is set up similarly to the slide. Tell students you need a recorder and a mathematician from each farm team. (I like to have two students completing the charts for each team in case one of them has difficulty with the math.) Have the two students from each team go to the chart and make sure one of them has a marker. Now ask for a volunteer from each team to be the first farmworker and give that student a marker (seed drill). Ask each farmworker to get ready. Prepare your stopwatch for the start and say "Go!" Each worker will go to the back of the room, grab the LOAN, and return to the front of the room. The workers will use the marker to write CORN on the field as many times as they can. When time reaches 30 seconds, say "Stop!"

6. *Display slide 6.* Tell students you are going to take them through an example chart before they complete the charts for their own farms. Tell them to record the example on the first chart on Handout 1: "Simulation Record Sheet." Take the students through the example, reminding them how to compute each value. Next, count the number of acceptable bushels of CORN for each farm. Corn must be printed in ALL CAPS, only complete words can be counted, and illegible words do not count. Tell the recorder for each farm how many bushels were accepted. Ask the mathematician and recorder to complete the chart for the first worker. Check the work and make sure the calculations are correct.

7. *Use slides 7, 8, and 9 in this step.* Ask each farm to add a worker and tell the two workers to decide who will write and who will run for the LOAN. Repeat the process described in steps 5 and 6 for workers two, three, and four. After worker four is added and the chart has been calculated, ask the students if the farm should hire any additional workers. If the MRP is less than the MFC, you will not hire any more workers. The point where MRP = MFC or the last point where MRP is greater than MFC may occur after adding workers two, three, or four. Identify how many workers each farm should hire.

8. *Display slide 10.* Explain to the students they will now use the simulation to determine whether returns to scale are increasing, decreasing, or constant. In round 1, they will have one labor resource and one capital resource. Run one round of the simulation and count the output. Use slide 10 to show the change in inputs for round 2. Ask each farm to record their output for round 2. Ask the students if output doubled, more than doubled, or was less than double from round 1 to round 2. Explain that if output has more than doubled from round 1 to round 2, returns to scale are increasing, if output has less than doubled from round 1 to round 2, then returns to scale are decreasing, and if output is exactly double from round 1 to round 2, then returns to scale are constant.

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9. *Display slide 11.* Tell students another way to calculate whether returns to scale are increasing, decreasing, or constant is to calculate the average total cost from round 1 to round 2. Ask the mathematician for each farm to calculate average total cost (ATC) for each round. If ATC has fallen from round 1 to round 2, returns to scale are increasing. If ATC increased from round 1 to round 2, returns to scale are decreasing. If ATC is the same from round 1 to round 2, returns to scale are constant.

10. *Distribute Handout 2:* "Marginal Analysis Practice Assessment." This is a formative assessment to practice the skills learned by participating in the simulation. Allow students to work independently or in groups on the assessment. Use the answer key to go over student responses or to score the assessment for a grade.

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Visual 1: Data Charts for Farms 1 and 2

Number of Farmworkers	Bushels of CORN	MPP	TRP	TFC	MRP	MFC
0	_____	_____	_____	_____	_____	_____
1						
2						
3						
4						
5						
6						

Visual 2: Loans for Farms 1 and 2

LOAN

LOAN

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Handout 1: Simulation Record Sheet

Essential Question One: What is the profit-maximizing quantity of farmworkers each farm should hire in this perfectly competitive labor market?

Perfectly competitive labor market
A market for labor in which the wage paid to workers is determined by the factor or resource market for that type labor and all workers are paid the market wage.

Total revenue product (TRP)
Price per unit of output multiplied by the total quantity of output produced each round: **TRP = Output X Price**

Total factor (resource) cost (TFC)
The wage per unit of labor multiplied by the total number of units of labor: **TFC = Wage X Total Number of Workers**

Marginal physical product of labor
The additional output (bushels of CORN) produced by each additional unit of labor (farmworker).

Marginal revenue product (MRP)
Price per unit of output multiplied by the additional quantity of output produced by adding an additional unit of labor: **MRP = MPP X Price**

Marginal factor (resource) cost (MFC)
The wage per unit of labor multiplied by the number of additional units of labor: **MFC = Wage X Additional Number of Workers Hired**

Assumptions for this simulation:

Price per unit of output = $8

Wage per worker = $5

Use the data chart below to record the sample data displayed on the slide.

Number of Farmworkers	Bushels of CORN	MPP	TRP	TFC	MRP	MFC
0	_____	_____	_____	_____	_____	_____
1						
2						
3						
4						
5						
6						

Handout 1: Simulation Record Sheet (Continued)

Use the data chart below to record the simulation data for your assigned farm.   **Circle:** Farm 1 OR Farm 2

Number of Farmworkers	Bushels of CORN	MPP	TRP	TFC	MRP	MFC
0	_____	_____	_____	_____	_____	_____
1						
2						
3						
4						
5						
6						

Essential Question Two: Are the returns to scale for a firm increasing, decreasing, or constant when doubling the quantity of labor and capital used in production?

Record Sample Chart from Slides Here

Number of Farmworkers	Bushels of CORN	MPP
0	_____	_____
1		
2		

1. (Select one) When labor and capital doubled,
   a. output more than doubled; increasing.
   b. output doubled; constant.
   c. output less than doubled; decreasing.

2. Calculate average total cost (ATC) for
   a. one unit of labor and one unit of capital.
   b. two units of labor and two units of capital.

If ATC increased from (a) to (b), returns are decreasing, if ATC decreased, returns are increasing, and if they are the same, returns are constant.

Record Simulation Data Here

Number of Farmworkers	Bushels of CORN	MPP
0	_____	_____
1		
2		

1. (Select one) When labor and capital doubled,
   a. output more than doubled; increasing.
   b. output doubled; constant.
   c. output less than doubled; decreasing.

2. Calculate average total cost (ATC) for
   a. one unit of labor and one unit of capital.
   b. two units of labor and two units of capital.

If ATC increased from (a) to (b), returns are decreasing, if ATC decreased, returns are increasing, and if they are the same, returns are constant.

Handout 2: **Marginal Analysis Practice Assessment**

The following chart shows the number of workers and the total product of labor for each number of workers in a bubble gum factory. Complete the chart and then answer the questions below the chart using the data you calculated. Assume the labor market is perfectly competitive and the factory can hire all the workers it wants at a market wage of $7.50 per worker. The company sells each unit of bubble gum for $0.50

Number of workers	Total Product of Labor (Units of Bubble Gum)	MPP	TRP	TFC	MRP	MFC
0	_____	_____	_____	_____	_____	_____
1	25					
2	45					
3	60					
4	70					
5	75					
6	70					

1. What is the marginal benefit of the second worker? What is the marginal cost of the second worker?

2. What number of workers should the bubble gum factory hire? Why?

3. Why do you think marginal revenue product becomes negative at some point as you add workers?

4. What would the firm need to change in order to add workers and still maximize profits?

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Handout 2: Marginal Analysis Practice Assessment (Continued)

5. Assume the total product of labor shown in the chart below is produced with factory workers and bubble gum machines. The factory workers earn $7.50 and the bubble gum machines cost $20 to rent during the production period for which the data are shown. If the bubble gum factory increased the number of workers from one worker to two workers and, at the same time, increased the number of machines from one machine to two machines, would the returns to scale be increasing, decreasing, or constant based on the data in the chart? Calculate using two different methods.

Number of workers	Total Product of Labor (One Bubble Gum Machine)	Total Product of Labor (Two Bubble Gum Machines)
0	_____	_____
1	25	40
2	45	65
3	60	75
4	70	82
5	75	89
6	70	82

Handout 2: Marginal Analysis Practice Assessment (Answer Key)

The following chart shows the number of workers and the total product of labor for each number of workers in a bubble gum factory. Complete the chart and then answer the questions below the chart using the data you calculated. Assume the labor market is perfectly competitive and the factory can hire all the workers it wants at a market wage of $7.50 per worker. The company sells each unit of bubble gum for $0.50

Number of workers	Total Product of Labor (Units of Bubble Gum)	MPP	TRP	TFC	MRP	MFC
0	_____	_____	_____	_____	_____	_____
1	25	25	$12.50	$12.50	$7.50	$7.50
2	45	20	$22.50	$10.00	$15.00	$7.50
3	60	15	$30.00	$7.50	$22.50	$7.50
4	70	10	$35.00	$5.00	$30.00	$7.50
5	75	5	$37.50	$2.50	$37.50	$7.50
6	70	-5	$35.00	-$2.50	$45.00	$7.50

1. What is the marginal benefit of the second worker? What is the marginal cost of the second worker?
   Marginal benefit = $10; marginal cost = $7.50

2. What number of workers should the bubble gum factory hire? Why?
   This firm should hire three workers. The MRP of the third worker is equal to the MFC of the third worker. This is the profit-maximizing number of workers to hire.

3. Why do you think marginal revenue product becomes negative at some point as you add workers?
   The factory does not have enough factors of production for all the workers in the factory. They are beginning to distract one another and get in one another's way.

4. What would the firm need to change in order to add workers and still maximize profits?
   The factory would need to invest in capital or factory size in order for more than three workers to produce a marginal benefit greater than the marginal cost of the workers.

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Handout 2: Marginal Analysis Practice Assessment (Answer Key Continued)

5. Assume the total product of labor shown in the chart below is produced with factory workers and bubble gum machines. The factory workers earn $7.50 and the bubble gum machines cost $20 to rent during the production period for which the data are shown. If the bubble gum factory increased the number of workers from one worker to two workers and, at the same time, increased the number of machines from one machine to two machines, would the returns to scale be increasing, decreasing, or constant based on the data in the chart? Calculate using two different methods.

Number of workers	Total Product of Labor (One Bubble Gum Machine)	Total Product of Labor (Two Bubble Gum Machines)
0	_____	_____
1	25	40
2	45	65
3	60	75
4	70	82
5	75	89
6	70	82

To calculate returns to scale, we can use the percentage change in output method or the change in average total cost method. Change in output method uses the following formula:

[(Total Product of Labor with two workers and two machines) - (Total Product of Labor with one worker and one machine) / (Total Product of Labor with one worker and one machine)] X 100

[(65 – 25) / 25] X 100 = 160%

Returns to scale are increasing because output increased by more than 100% when labor and capital increased by 100%.

To use the average total cost method, calculate the average total cost (ATC) for one worker and one machine. Then calculate the ATC for two workers and two machines. Returns to scale are increasing if ATC falls, decreasing if ATC rises, or constant if ATC remains the same.

ATC = (wage X # of workers) + (rent X machines) / TPL ATC = ($7.50 X 1) + ($20.00 X 1) / 25 = $1.10

ATC = ($7.50 X 2) + ($20.00 X 2) / 65 = $.85 – Returns to scale are increasing