MARYLAND COOPERATIVE EXTENSION
UNIVERSITY OF MARYLAND
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Fact Sheet

Fact Sheet 548

Using Economic Principles To Manage Your Farm

To make sound business decisions, managers must understand and be able to use the principles, tools and techniques of economic analysis. Using this fact sheet, farm managers will learn how to use basic economic principles, such as profit maximization, substitution and enterprise selection.

Profit Maximization

Profit maximization is based on the physical and economic relationships of inputs and outputs and indicates the optimum level of input use.

Physical Relationship

The physical relationship relates output to different levels of input. It sometimes is called the input-output relationship, or the factor-product relationship. In order to isolate the effect on output of a particular input, other inputs are held constant and output is measured with changes in the amount of the particular input used. The inputs held constant are called fixed inputs and the input varied is called a variable input.

For each level of variable input used, there is a corresponding level of output called total physical product (TPP). From TPP and the variable input (X_1), average physical product (APP) and marginal physical product (MPP) can be calculated. APP represents output per unit of input and is calculated by dividing TPP by the respective level of X_1 (APP = TPP/X_1). MPP is the addition to TPP for a unit change in X, and is calculated by dividing the change in TPP by the change in X_1 (MPP = ΔTPP/ΔX_1).

How do the variables relate? As X_1 increases, TPP increases until the seventh input level is used (Table 1, Figure 1). At this point, TPP actually declines. This can happen, for example, if the farmer uses too many units of X_1 relative to the fixed input(s). For example, too much fertilizer can burn a crop and depress output. Too many seeds planted per acre can cause overcrowding and a reduced yield.

As X_1 increases, APP first increases, reaches a maximum, and then begins to decline. In short, at early levels of input use, APP increases and then declines. Note that APP is listed on the particular input level (Table 1). However, since MPP is calculated as a change in output for a unit change in input, it represents the change between the respective input and output levels and is listed on the midpoint of X_1. MPP increases, reaches a maximum, and then declines to a negative value as X_1 increases from six to seven units (Table 1). MPP and APP are related in that APP will increase if MPP is greater than APP. APP will decline if MPP is less than APP. Consequently, MPP and APP are equal when APP is at a maximum. The relationships are clear if one thinks about needing an additional yield higher than the average to raise the average, or vice versa.

In the physical relationship, APP and MPP are used to delineate the rational region of production for X_1. The rational region of production begins at the peak of APP and continues to where MPP is equal to zero (Figure 1). The reasoning is that one would not want to use (a) less input than at maximum APP because APP is increasing to maximum APP or (b) more input than where MPP equals zero, because TPP will decrease absolutely if MPP is negative.

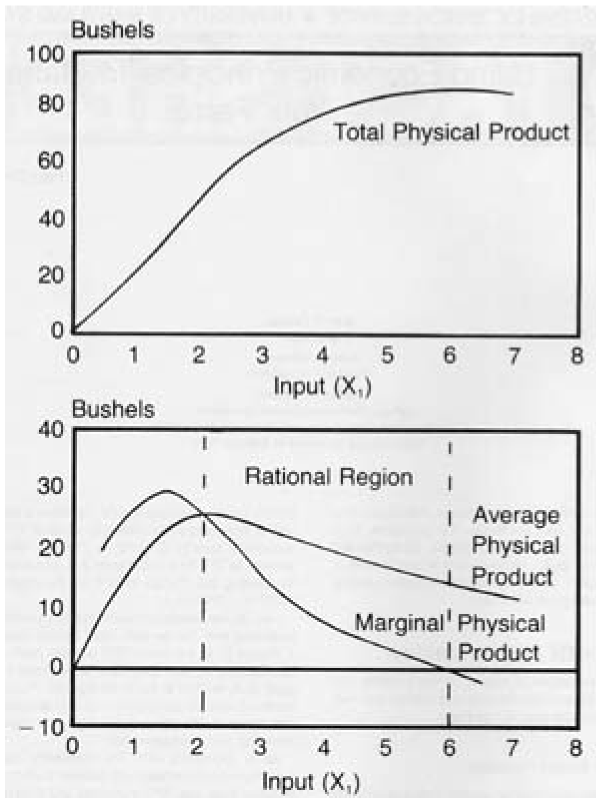

Figure 1. Input and output relationships for variable input.

The physical relationship indicates the farmer should produce in the rational region of production. However, it does not indicate the exact level of input to use within the rational region of production. To determine this point, variable input price and output price are required.

Table 1. Input and output relationships and optimal level of input use[a]

Variable input (X_1)	Output or total physcial product (TPP)	Average physical product (APP) $\frac{[TPP]}{X_1}$	Marginal physical product (MPP) $\frac{[\Delta TPP]}{\Delta X_1}$	Marginal value product (MVP) ($MPP \cdot P_{TPP}$)	Marginal input cost (MIC) (P_{X1})	Total value product (TVP) ($TPP \cdot P_{TPP}$)	Total Cost X_1 ($X_1 \cdot P_{X1}$)	Net ($TVP-TC_{X1}$)
Number of units	-------------	Bushels	-------------	----------------------		Dollars	----------------------	
0	0	0.0				0	0	0
			20	60	15			
1	20	20.0				60	15	45
			30	90	15			
2	50	25.0				150	30	120
			20	60	15			
3	70	23.3				210	45	165
			10	30	15			
4	80	20.0				240	60	180
			5	15	15			
5	85	17.0				255	75	180
			2	6	15			
6	87	14.5				261	90	171
			-2	-6	15			
7	85	12.1				255	105	150

[a]The price of X_1 is \$15 per unit The price of output (TPP) is \$3 per bushel

Economic Relationships

Economic relationships allow one to compare costs and returns associated with using additional units of X,. If the cost of the added input--marginal input cost (MIC)--is less than the return from the added input-marginal value product (MVP)--it is profitable to add another unit of the input. The optimal level of input use occurs where MVP equals MIC (Table 1, Figure 2). In Table 1, the optimal level occurs when the fifth input is added. Since this level adds the same amount to income as to cost, input level four has the same net return. This is shown in the last column of Table 1 where Total Cost of X, (TC_{x1}) is subtracted from Total Value Product (TVP) to get the net return above the cost of X,. The optimal level of input use for the variable input occurs where the net (TVP - TC_{x1}) is greatest.

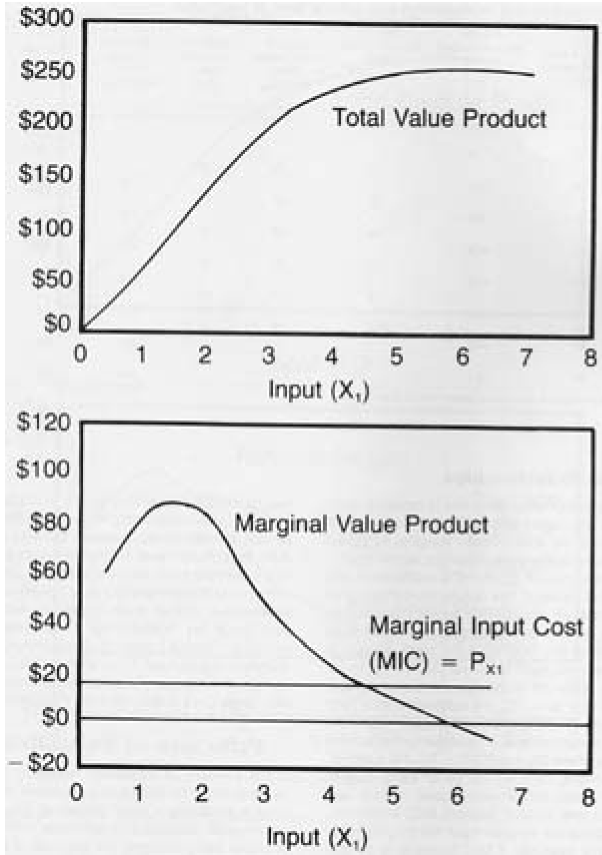

Figure 2. Optimal level of input use.

In many cases, there will not be an exact equality between MVP and MIC. In such a case, add the variable input as long as MVP exceeds MIC. In this way, net return above the variable input will be greatest at this point. For example, if MIC happens to be $25 instead of $15 per unit, input level four would be selected since MVP = $30 and is above the new $25 input cost. If one added the fifth level of input, only $15 would be added to income for the $25 expenditure on X^1. Adding a fifth level of input would not be a wise choice.

Selecting the optimum level of input use does not guarantee a profit from the enterprise. For example, selecting the optimal amount of fertilizer does not assure that the corn enterprise will be profitable. Why not? There are other costs associated with corn production. If costs exceed revenues, there is a loss. However, the optimum level of input use does assure that one makes the most money or loses the least amount of money at the optimal input level. For actual research examples of optimal levels of nitrogen fertilizer, see Fact Sheet 391 "Methodology for Determining Economically Optimal Levels of Nitrogen Fertilizer" and Maryland Agricultural Experiment Station Technical Bulletin 494 *Nitrogen Fertilization of Conventional and No-Tillage Corn in Maryland: An Economic Analysis.*

Principle of Substitution

The principle of substitution concerns substituting inputs to obtain the least cost combination of the inputs used in producing a given amount of output. Certain inputs can be substituted for each other without the level of output being changed. For example, a farmer can substitute corn for barley, corn for oats, grain sorghum for corn, wheat for barley, protein supplement for concentrates, or roughages for concentrates over certain ranges in feed rations for various types and classes of livestock. Other examples of substitutions include fertilizer for land, water for land, labor for capital, and capital for labor through mechanization. The bottom line is that if output remains the same (assuming the same quality), substitute one input for another if cost is decreased.

In the rational region of production, inputs generally substitute for each other at constant or diminishing rates. Inputs that substitute at a constant rate do so at the same rate over the entire production process. That is, if 1 pound of input 1 replaces 2 pounds of input 2, there is a constant rate of substitution of two to one for the entire process. In such a case, calculate the cost of each input for the substitution rate and select the one with the least cost. There is no advantage to using a combination of the two inputs. If the inputs substitute at a diminishing rate over the production process, compare the way in which they substitute in production to the rate in which they substitute in the market. In short, a combination of the inputs will probably give a lower cost.

There are two ways to determine the least cost combination of inputs. In this fact sheet, the authors are examining the substitutions between two inputs. In such a case, the first way to get the least cost combination is to multiply the quantity used of input 1 by its price and add this amount to input 2 multiplied by its price. Calculate the combination in each respective ration and then select the feed ration with the least cost. The least cost is shown in the last two columns in Table 2 under ration cost. The cost for rations B and C is the same in case one, because, between rations B and C, 5 pounds of protein were added (5 lb x $0.10/lb = $0.50 cost increase) to save 10 pounds of concentrates (10 lb x $0.05/lb = $0.50 cost savings). The same cost will result for any ration combination when the two inputs substitute in production at the same rate as they substitute in the market. Determining the least cost can be a cumbersome process if there are many input price changes, and in particular if the respective input prices do not change in proportion. The ration cost for prices that did not change in proportion is shown in the last column of Table 2, where the price of protein increases to $0.12 per pound without any change in the price of concentrates. Now, the least cost ration is ration B.

Rather than calculate the ration cost for an infinite number of price combinations, compare the rate at which the inputs substitute in production--substitution ratio (SR)-with the way the inputs substitute in the market--price ratio (PR) (Table 2). SR is calculated by dividing the change in the replaced input ($_2$) by the change in the added input (X_1), ($SR = \triangle X_2/\triangle X_1$). PR can be determined by dividing the price of X, by the price of X_{21} ($PR = P_{X1}/P_{X2}$).

The least cost combination is where SR equals PR, or when we move from ration B to ration C in Table 2 for a P_{X1} of $ 0.10 per pound and a P_{X2} of $0.05 per pound. Because SR and PR are equal for the change from ration B to ration C, rations B and C also have the same cost. What if there is no equality? Do not let SR become less than PR. This is shown in Table 2, under PR (2), where PR is 2.4. SR compared with the second PR indicates ration B is the least cost. This is verified in the last column where ration B has the least cost of $19.70 to produce the same amount of pork.

Because SR will not change unless additional research is conducted on the physical relationships, one can calculate alternative PR's as feed prices change, and quickly select the least cost rations by comparing the new PR to the unchanged SR.

The least cost ration does not ensure a positive net return from pork production because there are other costs of production. However, given the output and other costs, net return will be greatest or loss the least if the least cost ration is used to produce the output.

Table 2. Economic relationships when producing an equal amount of pork

Feed ration	Protein (pounds) X_1	Concentrates (pounds) X_2	Substitution ratio (SR) $(\Delta X_2/\Delta X_1)$	Price ratio (PR) (P_{X1}/P_{X2}) (1)	Price ratio (PR) (P_{X1}/P_{X2}) (2)	Ration costs (\$)[a] (1)	Ration costs (\$)[a] (2)
A	30	325				19.25	19.85
			3.0	2.0	2.4		
B	35	310				19.00	19.70
			2.0	2.0	2.4		
C	40	300				19.00	19.80
			1.2	2.0	2.4		
D	45	294				19.20	20.10
			0.8	2.0	2.4		
E	50	290				19.50	20.50

[a]Ration cost (1) is based on X_1 priced at \$0.10 per pound, and X_2 priced at \$0.05 per pound. Ration cost (2) is based on X_1 priced at \$0.12 per pound, and X_2 priced at \$0.05 per pound.

Enterprise Selection

Farmers should select the most profitable combination of enterprises from among the many enterprises that could be produced on their farms, given a fixed amount of resources. Farmers find themselves with limited and fixed resources and should select the enterprise combination that will maximize income for the given set of resources. The manner in which enterprises combine depends on the relationships between enterprises. The relationships can be competitive, complementary or supplementary.

Competitive Enterprise Relationships

Competitive enterprises compete at the same time for a limited resource. Enterprise A is competitive with enterprise B if a transfer of resources from A to B causes output of B to increase and output of A to decrease. For example, corn and soybeans require an acre of land at about the same time. When the acre is used for corn production, it cannot be used for soybeans. The competitive relationship could also be true for limited labor, operating capital and equipment. In such cases, there is a substitution of the production of one enterprise for another, given the use of the limited input at the same time. In general, enterprises will substitute for each other at a constant or increasing rate. Under the constant rate of substitution, each additional unit of output from the added enterprise replaces a constant amount of the replaced enterprise. For the increasing rate of substitution, more and more units of the replaced output is given up for the output gained from the added enterprise. This substitution is calculated as follows:

$$SR = \frac{\text{Quantity of output replaced } (\Delta Y_2)}{\text{Quantity of output added } (\Delta Y_1)}$$

The quantity changes in output are changes in the output for each product between two combinations of the enterprises. This can be seen in Table 3, where a fixed amount of the resource can be used to produce only Y_2 in combination number 1 or to produce only Y_1 in combination number 7. A combination of Y_2 and Y_1 can be produced using a fixed amount of the resource distributed between Y_1

and Y_2 in combination numbers 2 through 6. The SR column shows the number of units of output of enterprise Y_2 that have to be given up for one more unit of output of Y_1.

Profit is maximized when SR is equal to the PR of Y_1 and Y_2(PY_1/PY_2). Prices may be used in the ratio as long as total production costs are the same for each combination of Y_1 and Y_2. Otherwise, the ratio would be calculated by using profit or net return per unit of Y_1 and Y_2. For this example, use prices of Y_1 and Y_2. The optimal combination of enterprises in Table 3 occurs as we move from combination number 4 to combination number 5 where SR = PR. Because SR and PR are equal, combination numbers 4 and 5 would be equally profitable. Moving from 4 to 5, the same amount of income is given up from Y_2 as gained from getting more of Y_1. In many cases, there will not be an exact equality of SR and PR. In such a case, substitution of Y_1 for Y_2 should continue as long as PR is greater than SR. This means that the additional income will exceed the lost income, and the substitution will increase income. Net return also is increased because total cost is the same for the fixed resources used in the various combinations to produce Y_1, Y_2 or a combination of the two. For example, if PR in Table 3 happened to be 3.5, combination number 6 would be the optimal combination of Y_1 and Y_2. If PR is less than 0.75, the farmer should produce all Y_2. If PR is equal to or greater than 5.0, the farmer should produce all Y_1 for maximum income. Because total cost is the same for the fixed amount of the inputs for all combinations of Y_1 and Y_2, the most profitable combination can be selected by calculating gross income for each enterprise combination and selecting the one that is highest, or, $P_{y1}Y_1 + P_{y2}Y_2$ for each enterprise combination.

Table 3. Profit maximization for two enterprises given a fixed amount of the resource

Combination number	Units of output (Y_1)	Units of output (Y_2)	Substitution ratio (SR) ($\Delta Y_2/\Delta Y_1$)	Price ratio (PR) (P_{Y1}/P_{Y1})
1	0	4,600		
			0.75	2.00
2	800	4,000		
			1.00	2.00
3	1,400	3,400		
			1.40	2.00
4	1,900	2,700		
			2.00	2.00
5	2,300	1,900		
			3.00	2.00
6	2,600	1,000		
			5.00	2.00
7	2,800	0		

If the enterprises substitute for each other at a constant rate of substitution, the farmer should produce one or the other to maximize profits. There is no advantage to producing a combination in such a situation. Calculate the net income from each enterprise and select the one with the greater income.

Complementary and Supplementary Enterprise Relationships

Even though the most common relationship is competitive, certain added or increased enterprises may help or not affect the level of output of other enterprises. If resources are taken from one enterprise and put into another enterprise and the output of both enterprises increases, there is a complementary enterprise relationship. If the resources are moved from one to the other enterprise and the output of one increases without affecting the output of the other, there is a supplementary enterprise relationship. For example, a complementary relationship could result from rotating a legume crop with corn over several production periods. (The legume crop adds nitrogen to increase corn yield and increases the legume crop output.) Also, in some areas of the United States, land is left fallow to conserve moisture to increase total production of a crop over time as compared to the production of a crop on a continuous basis. A supplementary relationship could result from adding a few steers or hogs to run on pasture or following grain crop harvest, adding a small ewe flock, selling fishing or hunting rights, or planting a family garden since the primary livestock or crop enterprise would not be affected in terms of output. The relationships eventually become competitive since one enterprise cannot be increased indefinitely without affecting the output of the other enterprise.

Conclusions

Basic economic principles of profit maximization, input substitution and enterprise selection can be used in solving practical problems faced by farm managers in everyday decisionmaking. Farmers face the need for selecting the optimal level of input use, least cost combination of input, and the most profitable combination of enterprises from a large number of possible enterprises that could be produced on the farm.

Using Economic Principles To Manage Your Farm

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