CHAPTER 4

DETERMINING OPTIMAL INPUT USE

Maximizing profits is defined to be the level of output (production), or the level of inputs needed to produce the highest possible net return. *Net return* equals total revenues minus total cost. So to achieve maximum profits you may have to decide how much of an input to use.

To begin input analysis we must understand the basic principles of production, and how these principles relate to using the inputs to production. Inputs to production are resources such as land, labor, capital, and management.

## A. Analyzing Production Using a Single Input

This consists of relating the amount of an input needed to produce different levels of output. We will consider some production relationships in analyzing input use.

The *total production* is the production of an agricultural product received from using a certain input. For example, consider the quantity of corn produced while using different amount of nitrogen for the primary fertilizer. The following chart illustrates a hypothetical example of the relationship between the per acre production of corn with nitrogen fertilizer as the input. The production is sometimes called the *total physical product* or *TPP*.

| Nitrogen Amount (lbs)	Corn Yield (TPP) – bushels
110	130
120	145
130	165
140	170
150	153.5
160	153.5
170	152

As you can see, the production level (TPP) changes as different amounts of nitrogen are applied. For example, increasing the nitrogen from 110 pounds to 120 increases the corn yield per acre. However, increasing from 160 pounds to 170 actually decreases the yield per acre. We can also graphically illustrate this relationship.

Total Physical Product Curve
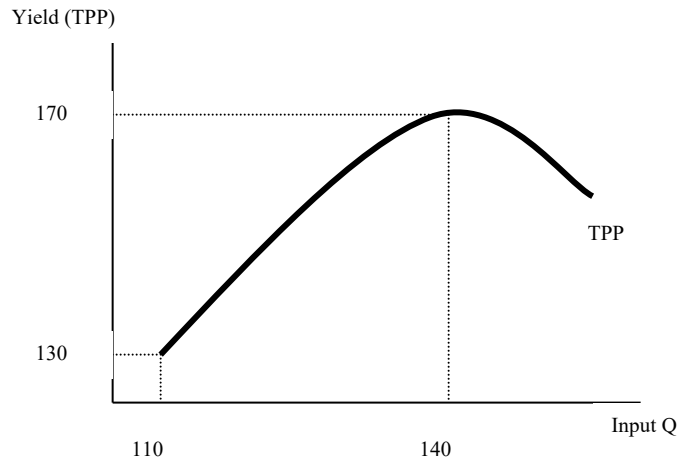
This relationship illustrates how production changes for different levels of inputs. Lower input levels contribute more of an increase to production levels than do the higher level of inputs. An example of this is a produce farmer who hires workers to hand pick produce. The first several workers increase production because they can get produce from the field quickly and efficiently. This is represented by the sharp increase in the TPP curve. However, there is a point where there are so many workers that they are bumping into each other and dropping the produce. This represents the downward sloping portion of the TPP curve where production is declining from the adding of inputs.

Consider again our earlier feed example.

Feed lbs	Daily Gain
10	1.0
12	1.2
14	1.57
16	1.8
18	1.9
20	1.7
22	1.0
24	0.3
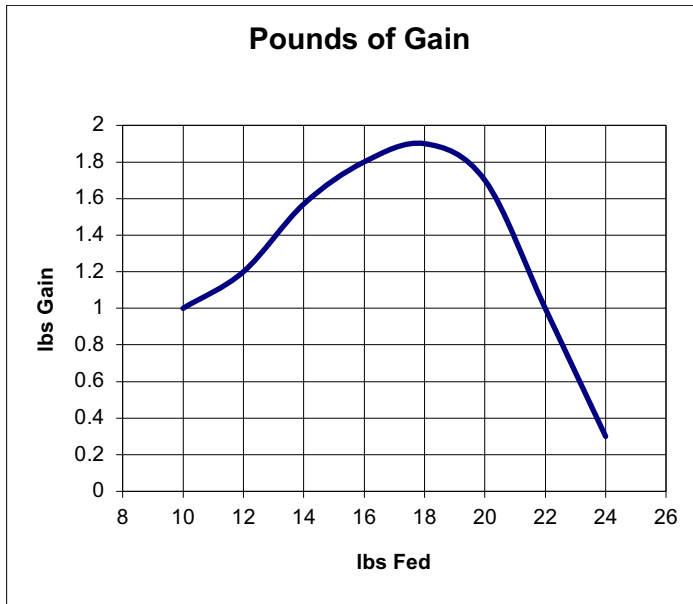
The increase of feed from 10 to 18 pounds increases daily gain. However, over 18 lbs of feed causes a decrease in gain, perhaps because of sickness or loss of fluids. The area of increase in

gain can be analyzed in more depth and examined to determine the optimal area of feed use. This is accomplished by looking at the average and marginal levels of production.

The *average production* or *average physical product (APP)* is the yield or TPP produced per unit of input used. For the example it would be the amount of corn produced for every pound of nitrogen fertilizer, or lbs of gain for every 1 lbs of feed fed. The average physical product is found using the following formula.

Average Physical Product (APP) = TPP / Quantity of Input

The APP should never be negative, because there cannot be negative production. The lowest that production can become is zero.
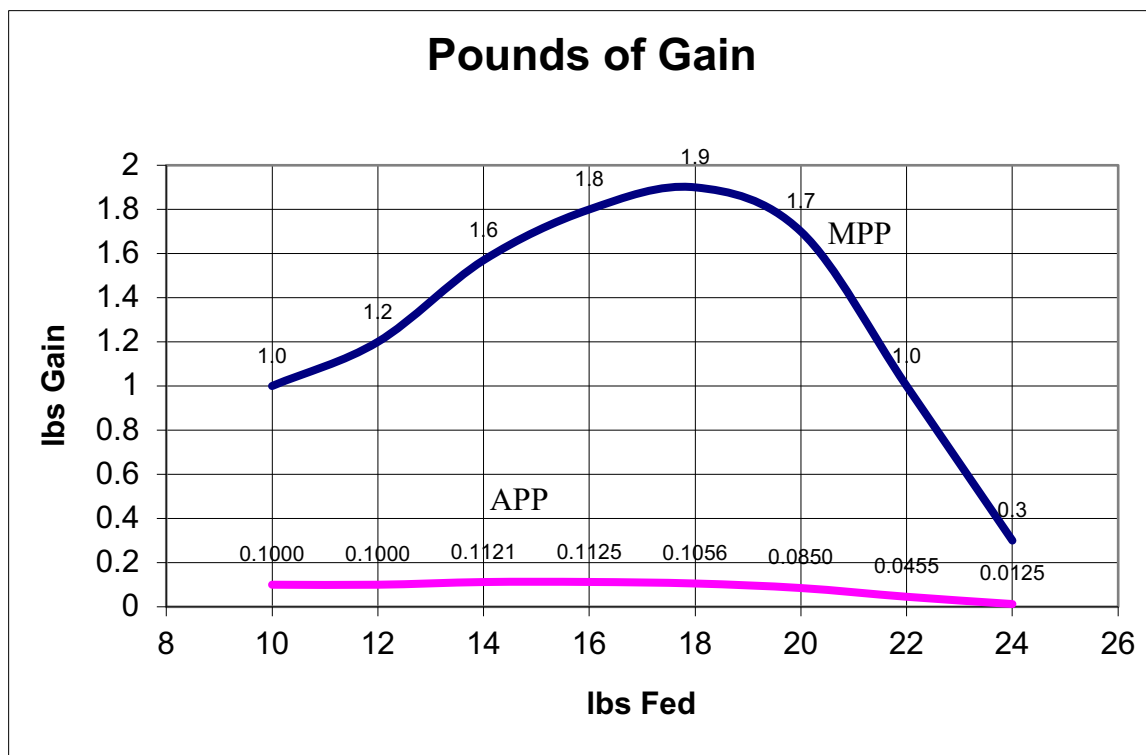
Nitrogen Amount (lbs)	Corn Yield (TPP) – bushels	Average Yield (APP)
110	130	1.181
120	145	1.21
130	165	1.27
140	170	1.214
150	153.5	1.023
160	153.5	.96
170	152	.894

The table shows that corn yield per pound of nitrogen peaks when 130 pounds are applied, and then steadily decreases. The average physical product is useful to inform the producer of the yield or bushels of corn production from each pound of fertilizer. For example, at 130 pounds of fertilizer, the yield is 1.27 bushels of corn per pound of nitrogen.

Another example is the feed effect on daily gain. The APP for this example is illustrated in the following table and graph.

Input X	TPP	APP
Feed lbs	Daily Gain	
10	1	0.1000
12	1.2	0.1000
14	1.57	0.1121
16	1.8	0.1125
18	1.9	0.1056
20	1.7	0.0850
22	1	0.0455
24	0.3	0.0125

Pounds of Gain

lbs Gain (y-axis): 2, 1.8, 1.6, 1.4, 1.2, 1, 0.8, 0.6, 0.4, 0.2, 0

lbs Fed (x-axis): 8, 10, 12, 14, 16, 18, 20, 22, 24, 26

Data labels (upper curve): 1.0, 1.2, 1.6, 1.8, 1.9, 1.7, 1.0, 0.3

MPP

APP

Data labels (lower curve): 0.1000, 0.1000, 0.1121, 0.1125, 0.1056, 0.0850, 0.0455, 0.0125

The graph illustrates APP reaching its peak at 16 lbs of feed (hard to tell without the numbers) and the table illustrates the value of APP at 0.1125, but what does the value represent? This represents 0.1125 lbs of gain for 1 lb of feed fed.

Marginal physical product is used to analyze the change in production from a change in the input level. The word marginal means "a change in." In our examples, the marginal principle involves the change in production resulting from each additional pound of fertilizer used in the ten-pound increments (110 to 120, 120 to 130, etc.) This is a very important concept in maximizing profits, because we are mainly interested in the change resulting from a decision.

For example, a corn producer is interested in what the per-pound change in production would be if he or she added another 10 pounds of fertilizer. Another example may be a custom steer fitter who is interested in the change in weight gain from feeding an additional pound of feed per day. The concept of marginal analysis is often what people are looking for. It can be considered the "bottom line for the decision."

The formula for marginal physical product is as follows:

Marginal Physical Product (MPP) = New TPP – Original TPP
Change in inputs

Using the current example the first marginal physical product to calculate is the 110 to 120 pounds of nitrogen affect on production:

$$145 - 130 / 10 = 1.5$$

In other words, there is a 1.5 bushel increase per pound of fertilizer added at the 110 to 120 lb. level.

The change in TPP is found by subtracting the new TPP from the original level. This keeps the increases positive and the decreases negative. To illustrate this, let's look at the MPP for 140 to 150 pounds of fertilizer:

$$153.5 - 170 / 10 = -1.65$$

This shows a 1.65 bushel _reduction_ in corn yield from adding a pound of fertilizer at the 140 to 150 level.

The negative marginal physical product (MPP) makes sense because our TPP does decrease at the fertilizer level 140 to 150 pounds (170 to 153.5). The remainder of the MPP figures are illustrated in the following chart.

| Nitrogen Amount (lbs)	Corn Yield (TPP) bushels	Average Yield (APP)	Marginal Physical Product (MPP)
110	130	1.181	--
120	145	1.21	1.50
130	165	1.27	2.00
140	170	1.214	0.50
150	153.5	1.023	-1.65
160	153.5	0.96	-1.65
170	152	0.894	-0.15

This shows that the maximum efficiency use of the fertilizer is from 120 to 130 pounds, where the marginal physical product is the greatest. This represents efficiency because it shows where there is the greatest gain in yield from increasing the input level by a pound. Using the previous feed use example, we analyze MPP along with the APP chart.

Input X Feed lbs	TPP Daily Gain	APP	MPP
10	1	0.1000	--
12	1.2	0.1000	.1000
14	1.57	0.1121	.1850
16	1.8	0.1125	.1150
18	1.9	0.1056	.0500
20	1.7	0.0850	-.1000
22	1	0.0455	-.3500
24	0.3	0.0125	-.3500

Pounds of Gain
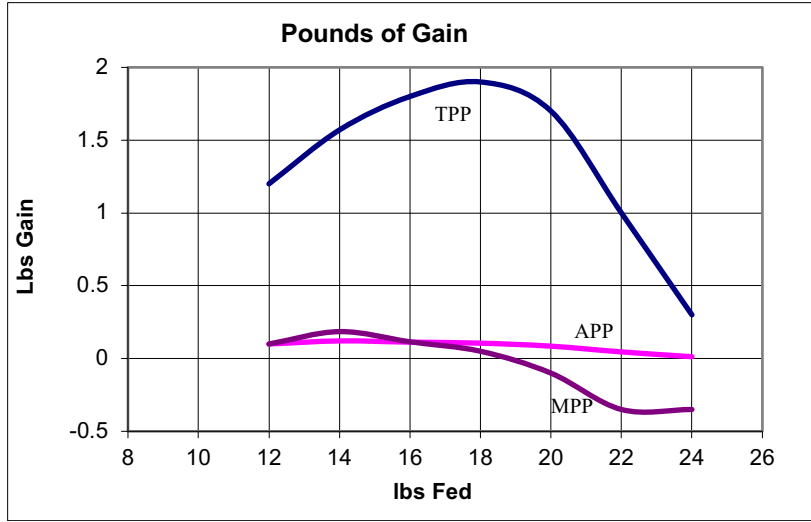
The highest MPP is reached from increasing feed from 12 to 14 lbs, with .1850 increase in gain from every 1 lbs of feed fed. The change in feeding from the change in 18 to 20 and on give negative change in production, and have corresponding negative MPP values. The highest MPP, measures the highest value of change is referred to as the point of inflection.

Graphically relating TPP, APP, and MPP also illustrates the various stages of production.

Pounds of Gain
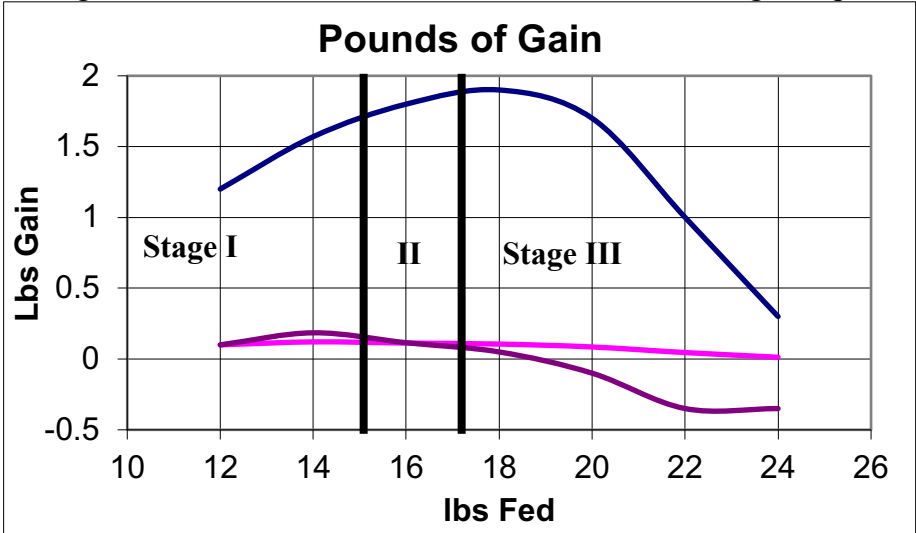
Stage I is the beginning stage of production. It is when inputs, such as fertilizer, and labor, are used to increase the yield (TPP). This is the entry stage of production because it begins production and has a large increase in yield, which is illustrated by the rising marginal physical product. Stage I ends when the marginal physical product is decreasing and is equal to the average physical product.

Stage II is called the efficient or rational stage of production, because it is where the maximum production is reached. Efficient production occurs when the producer is able to produce the most yields and is still maintaining revenue greater than the cost. Exactly where the economically efficient level of production is (this will be discussed later, but it does occur in this second stage of production).

Stage II begins where stage I ends and continues until where is a decrease in production, which for the example occurs at about 18 pounds of feed. Since MPP is the change in yields resulting from increasing input levels, the MPP is zero and then negative when yields decrease from adding inputs. This marks the end of stage II.

Stage III is the stage that holds negative returns. This concept states that there is a decrease in production from adding any additional inputs, which again is represented by a zero and then a negative MPP. An example of this is adding too much nitrogen to our production of corn, or too much feed. An amount beyond the 18 pounds will decrease the production, and that is where the negative MPP begins.

Now that we have characterized the stages of production, how do we determine what amount of nitrogen is needed for maximum profits? We know it is in Stage II, but at what level? To determine this we must add dollar values to the previous measures of production and inputs, which allows us to estimate the optimal level of inputs.

B. Optimal Profit Input Use

To find the maximum profit from using an input we need to analyze the value of product and compare it to the inputs cost. This is accomplished by determining marginal value product and marginal input cost.

Marginal value product is the MPP, except it represents a dollar value instead of an amount. This is usually denoted as MVP, and it represents the change in value from a change in an input use. Continuing the same feed example, the MVP is the dollar value of corn production from a pound increase in feed.

Marginal Value Product = MPP * production value per unit

Use the following feed example:

Input X	TPP	APP	MPP	MVP, price	MIC
Feed lbs	Daily Gain			$.65/lbs	Feed 0.072
10	1	0.1000	--	--	
12	1.2	0.1000	0.1000	$0.0650	0.072
14	1.57	0.1210	0.1850	$0.1203	0.072
16	1.8	0.1125	0.1150	$0.0748	0.072
18	1.9	0.1056	0.0500	$0.0325	0.072
20	1.7	0.0850	-0.1000	($0.0650)	0.072
22	1	0.0455	-0.3500	($0.2275)	0.072
24	0.3	0.0125	-0.3500	($0.2275)	0.072

So the MVP illustrates that there is a gain in revenue from adding 10 to up to 18 pounds of feed, but exactly how much gives us the maximum profit? To find this we need to consider the cost of the feed.

Marginal input cost is cost for an input, and is equal to its price per unit, which in this case is the cost per pound of feed (MIC = $0.072 per lb, or 7.2 cents per lb.) The optimal input level is where the marginal value product is equal to the marginal input cost. This is because our goal is to maximize profit and to accomplish this we are making sure that the change in revenue generated (MVP) is greater than the input cost (MIC). This concept is summarized in the following:

Maximum profits: MVP is > or = MIC

Assuming there is no limit on the availability of feed, we would produce up until the MVP is equal to the MIC. With this idea, we can get the optimum level of production, while considering the change in cost compared to the change in revenue. This point of the optimal input level will also give us a maximum level of profit considering the single input of feed.

This maximum profit input level is where the MVP equals the MIC, which is between 16 and 18 pounds of feed. The change in revenue is compared to the change in cost, and as long as the change in revenue exceeds the change in cost we should keep using the input. This determines profit to be reached somewhere between 16-18 lbs of feed. The MVP is 0.072 between 16-18 lbs of feed, which is equal to the MIC of 0.072.

This is an important concept so let us look at another example of the use of equating MVP and MIC.

The concept of marginal value product can also be applied to selecting from several different enterprises to invest in. Consider the following example on selecting from several investments.

Capital to Invest (MIC)	Beef $MVP	Machinery $MVP	Dairy $MVP
1st $100	160	165	175
2nd $100	155	158	168
3rd $100	150	142	156
4th $100	140	132	148

Each enterprise has values, or MVPs, that are already calculated based on investing $100 dollars, which is the MIC. Looking at all of the MVPs, there are none below the MIC (<100), so they all are acceptable investments. In every case, we could invest $100 and earn more than $100. However, what if we were limited in the total amount that we could invest?

How do we choose the optimal combination of investments that would maximize our total value earned?

Example 1: Assume that we had only $400 dollars to invest.

With a limited resource of $400, we can make four $100 investments. We must choose the highest MVP available, until we have either invested the full amount, or the next MVP is less than our MIC. (We wouldn't want to invest $100 to make $95.) This choice is:

Dollar Investments with $400 limit	MVP
Dairy Investment ($200)	$175 and $168
Machinery Investment ($100)	$165
Beef Investment ($100)	$160

This is because the highest first two MVP's are in the Dairy Investment ($175 and $168). The third $100 investment goes to the third highest MVP, which is a Machinery Investment with a MVP of $165. The final $100 dollars goes to the fourth highest MVP of $160, which is in the Beef enterprise.

Determining optimal use of an input involves understanding how that input affects production, and determining values of production and cost of input to determine optimal use. What happens if the cost of an input rises, until it is always above the MVP? Technology will create new inputs to do the same job, but for less money. This enables production to still continue because of the lower cost input. The analysis of this single input is using the change in revenue and equating it to the change in cost (MR = MC). The concept is that if you can increase revenue $1.00, with an additional cost of $.90 you should do it. The next use of another $1.00 may cost $.98, but you still have profit and should do it as well. In fact, you should keep increasing production until the point when the increase in revenues equals the increase in cost, and at that point there is no need to increase any further.

Our study at this point has only considered one input, but in production there are many to consider. For example, the feed input of 18.2 lbs may the optimal amount to produce 1.95 lbs of daily gain. This may be the feed use profit, but to reach this level, the de-worming program might have to be for every 15 days. The worming use is likely not profitable at that level. Had we only considered wormer as an input, it may have been determined to be targeting a gain of only, for example, 1.60 lbs every day.

To determine exactly what gain is overall profitable we must analyze all costs. This analysis is discussed in the next chapter.