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Frontiers in Agricultural Production Economics Research

This chapter provides an introduction to topics of current interest to agricultural economists conducting research on problems of importance in agricultural production economics. The chapter is organized around three major topic areas: (1) the treatment of management in a production function, (2) technological change and its link to a production function, and (3) unresolved conceptual issues relating to the estimation of production functions from actual data.

Key terms and definitions:

Management Functions
Risk Bearing
Entrepreneurship
Technological Change
Estimation of Production Functions
Correlation

23.1 Management and Agricultural Production Functions

The manager of a farm performs three functions; the manager (1) selects the amount of each output and mix of outputs to be produced in the production process, (2) determines the proper quantity of each input to be used and allocates inputs among the various outputs, and (3) bears the risk associated with the production and marketing of the products. Some agricultural economists use the term *entrepreneurship* to describe the manager's risk bearing function. The marginal conditions outlined in this book play a key role in determining how a farm manager might best perform functions (1) and (2). As indicated in Chapter 20, the manager's willingness and ability to bear risk depends in large measure on his or her psychic makeup.

23.1.1 Alternative Approaches to Management

Some agricultural economists have attempted to treat management just as any another input to the production function, to be measured and treated in much the same way as inputs such as seed and fertilizer. Such an approach might yield a production function such as

†23.1 $$y = Ax_1^a x_2^b M^c$$

where y is an output, x_1 and x_2 are two variable inputs, and M is management with an elasticity of production of c. With a specification such as equation †23.1 , management enters the production function in a multiplicative fashion, and the marginal products of all the other inputs contain management in them.

An attempt is then made to locate or develop some measure of the skill of the manager. A sometimes used measure is the years of education of the farm manager. Analyses based on this idea have rarely, if ever, yielded anything. Usually, the researcher finds that the measure of management was unrelated to output, and the faulty measurement of the management skill is blamed for the bad results.

Agricultural economists who attempt to deal with the concept of management using an approach such as this might better find fault with the conceptual logic. Management is not an input as such. Rather the skill of the manager largely determines the amount of the other inputs to be used in the production process, as well as how these inputs are to be allocated in the production process. Good managers are those who know and can make use of the marginal principles and are willing to assume the requisite amounts of risk.

Moreover, although marginal principles can be learned in a class in production economics, farm managers without the benefit of a college course have often become aware of and make use of these principles, even though they may not be aware of the formal logic. A good deal of marginal analysis is nothing but a formal presentation of common sense; and many people have common sense with regard to decisions with respect to how much input should be used, even though they lack the formal training in agricultural economics.

Formal education may do little to change the manager's psychic makeup. The well ! educated manager would not necessarily be willing to assume greater amounts of risk than the manager who lacked an extensive formal education. It is not surprising that education is not necessarily a good measure of a manager's skills.

Another approach is to assume that management is not a separate variable but rather, influences the production elasticities on the remaining variables of the model. Such logic would lead to a production function with variable elasticities of production

†23.2 $$y = Ax_1^{a(M)}x_2^{b(M)}$$

where *a* and *b* are individual production elasticities which are each a function of the "level" of management *M*.

This model suggests that a given quantity of fertilizer will somehow produce greater output on the farm of a skilled manager than on the farm of a manager who lacks skill. Just what the skills are that make a difference is not clear. Good managers have no magical skills that make it possible for them to get around the technical relationships that govern and limit the amount of output that can be produced from a given amount of input, but they are keenly aware of the amount and allocation of inputs needed to produce the greatest net revenue within the constraints imposed on the farm.

A final possibility is that the manager's skills are embodied in the coefficient or parameter *A*. This example is similar to the first example except that management is not treated as a separate variable. The parameter *A* in a Cobb Douglas type production function is a sort of garbage dump, embodying the collective influences of everything that the researcher did not wish to treat as an explicit input in the production function. One possible equation for *A* is

†23.3 $$A = M^c 2$$

where 2 is the parameter with the management variable excluded.

This approach leads back to the same equation as that listed in the first approach, but possibly avoids the problem of having to find a separate measure of management. The alternative of not measuring management as a separate variable assumes by default that the manager's skills do not vary across farms, which may be equally incorrect.

23.1.2 Management and Profit Maximization

Some economists have traditionally aggregated inputs into four categories: land, labor, capital, and management. In fact, the treatment of management in an agricultural production function as a separate variable probably had its roots in this input categorization. Each input category receives a payment. Land receives rent, labor receives wages, capital receives interest, and management receives profit. Profit is what is left over after all other inputs or factors of production have received their payments.

The model of pure competition in long run equilibrium yields zero profit. It is not entirely clear whether this means that the manager's skills go unrewarded. If the manager's skills were unrewarded, then the manager of a firm operating in a purely competitive long run equilibrium is indifferent to producing or shutting down. But if the manager were getting no return for his or her skills, he or she would be better off shutting down the operation, rather than wasting time doing things that net no return. In short, it is not clear why any firm should want to produce in the long ! run equilibrium of pure competition.

A critic might argue that in long ! run competitive equilibrium, a manager's skills are no longer needed, and therefore it is not important that these skills go unrewarded. Moreover, long ! run equilibrium is perhaps never achieved, and that managers keep producing because of the potential short-run pure profits. This same critic might also say that it is foolish to think about such things because no industry operates in a purely competitive environment.

Even Euler's theorem is problematic. Should management be treated as one of the inputs to the production process to be paid its *VMP*? Or does management simply get what is left over after all other factors of production have received their respective *VMP*'s? If so, management gets a return only if the production function is homogeneous of a degree less than 1. But is it not proper for management to earn its *VMP* just like every other input? Maybe Euler's theorem applies only to the long ! run competitive equilibrium, and a manager is not needed. Euler the mathematician derived an algebraic relationship and was rather unconcerned as to the competitive conditions under which economists might assume that the relationship held.

The treatment of management within a production function remains a serious and unresolved problem in agricultural production economics. Each approach for the treatment of management in the production function has logic behind it, but it is easy to find fault with each approach as well.

23.2 New Technology and the Agricultural Production Function

New technology usually comes in the form of an improvement in one or more of the inputs used in the production process. There are many possible impacts of new technology on agriculture.

An improvement in one of the inputs might raise its marginal product and increase the elasticity of production for that input, causing the slope of the new production function to be greater than the old production function at a given level of input use. An improvement in one of the inputs might cause the marginal product of one or more of the other inputs to the production process to increase. An increase in the slope of the production function will cause the *VMP* for all the affected inputs to rise, resulting in an increased profit-maximizing level of use for any input whose marginal product is affected by the technology. The development of hybrid seed corn not only raised the marginal product of seed, but undoubtedly also increased the marginal product of other inputs, such as nitrogen fertilizer.

A second and perhaps less likely possibility is that the new technology shifts the intercept but not the slope of the production function. Output with the new production function is increased relative to the old production function, but the marginal products of the inputs are unaffected. In this case, the profit-maximizing level of input use will not change, but the output will increase at the profit maximizing level of input use.

A third possibility is that the new technology lowers the per unit cost of production. The new technology is adopted because with the new technology, one or more of the input prices are reduced. This amounts to a reduction in the price (v) of input x. As a result of the price reduction, the profit-maximizing level of input use will be increased. An example of a cost-reducing technology is the development of a new pesticide that is as effective as the old but at a lower per acre cost.

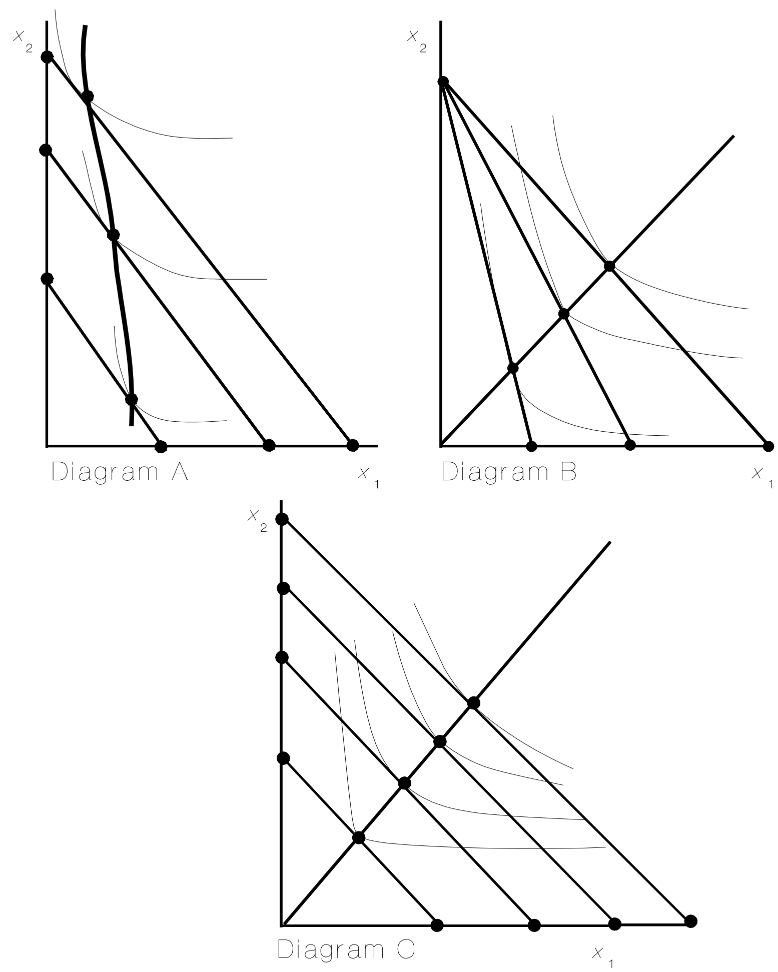

Figure 23.1 Some Possible Impacts of Technological Change

New technology will usually cause output to increase over time. Figure 23.1 illustrates some possible effects of new technology in a two input setting. Diagram A illustrates a case in which the new technology makes input x_2 more productive relative to input x_1. Isoquants farther out are positioned closer and closer to the x_2 axis.

New technology could cause the per unit cost of the input to decrease, resulting in increased use of the input experiencing the price reduction for a given budget outlay (diagram B). An example would be the development of a new herbicide that was as effective at controlling a particular weed but at a lower cost per acre than before. Such a new technology may or may not affect the use of the other inputs, depending on the shape of the isoquants.

New technology could also change the shape of the isoquants and therefore result in an increase in the elasticity of substitution (diagram C). A large elasticity of substitution is desirable in that it allows for significant changes in the mix of inputs that can be used to produce a commodity in the face of changes in relative input prices and technology that makes possible the substitution of cheap inputs for expensive inputs. Technology that allows a farmer to produce methane from farm manure is an example.

23.2.1 Some Examples

Suppose that the production function is

†23.4 $$y = a + bx + cx^2$$

where

$$a, b > 0 \quad c < 0$$

If the new technology shifts the entire production function, without any change in the marginal product of x, the parameter a will have increased. It is unlikely that output would be produced in the absence of the input. An increase in the marginal product of x could occur as a result of the parameter b becoming larger or as a result of the parameter c becoming less negative. This is the probable impact of much new technology.

Now consider the production function

†23.5 $$y = \mathrm{a} + bx_1 + cx_1^{\,2} + dx_2 + ex_2^{\,2}$$

where a, b, c, d, and e are parameters.

New technology that affects x_1 will not change the marginal product of x_2.

Now suppose that the production function has an interaction term with a corresponding parameter f

†23.6 $$y = a + bx_1 + cx_1^{\,2} + dx_2 + ex_2^{\,2} + fx_1x_2$$

New technology that affects input x_1 will probably change the parameters b, c, and f. Since the parameter f is part of the *MPP* for x_2 also, the new technology for x_1 will change the *MPP* of both x_1 and x_2. Normally, f would be expected to be positive, such that the new technology would increase the marginal product of x_2 as well. New technology might also increase the value of f, even if f were negative.

Suppose the Cobb Douglas type of production function

†23.7 $$y = Ax_1^{\,a}x_2^{\,b}$$

One explanation for parameter A of the Cobb Douglas type of production function is that it represents the current state of the production technology at any point in time. A change in the parameter A will change the slope of the production function and the individual *MPP*'s for both inputs. The parameter A appears multiplicatively in each *MPP*. Moreover, changes in either a or b result in a change in the *MPP* for each input. Again a and b both appear in the *MPP*'s for x_1 and x_2.

If, as a result of the new technology, the price of one of the inputs declines, there will normally be an increase in the use of the input that experienced the price decrease. The use of the other inputs (that do not experience a price decrease) may increase, decrease, or stay the same, depending on whether the other inputs are technical complements, competitive, or independent.

23.2.2 Time and Technology

For an agricultural economist dealing with a problem in a static, timeless environment, the impacts of new technology are of little concern. A production function estimated from single period cross sectional data has as an underlying assumption the state of the technology that existed at the time for which the data are available.

However, if a production function is to be estimated from data over several production periods, technology does become of importance. Moreover, it is often difficult to find direct measures of the state of technology over time. Agricultural economists usually rely on some simple, if crude means such as the incorporation of a time variable into the production function. A simple time variable (for example, 1 for year 1, 2 for year 2, 3 for year 3, and so on) is a very inaccurate measure of technology but may represent an improvement on a model that failed to recognize that technology changed at all.

Suppose that the production function was to be estimated as a Cobb Douglas type of function

†23.8 $$y = Ax_1^a x_2^b$$

The parameter A could be defined as

†23.9 $$A = " + \$$$

where " is the parameter A with the impacts of technology (time) removed and \$ is the parameter associated with the change in technology. This approach would be most applicable in instances where there existed a gradual improvement in technology over a long period and it was difficult to determine which specific input categories are affected.

If the agricultural economist believes that the elasticities for only certain of the inputs are affected by the technology, the parameters for the affected inputs could be made a function of the measure of technology (in this case, time). For example, suppose that the new technology is thought to affect the elasticity of production for input x_1. The parameter a on x_1 could be defined as

†23.10 $$a = 2 + (T$$

where 2 is the base production elasticity and (is the change in the production elasticity with respect to a change in the technology per unit of time. More complicated functions could easily be developed that would allow for variable rates of change in the technology. The production function becomes a Cobb Douglas type with variable production elasticities.

Another approach would be simply to estimate separate production functions for each year in the data series. This would amount to a series of still snapshots of the state of technology that existed for each period. An approach such as this can provide a good deal of information, since separate estimates of every parameter for every period are available, but a lack of the data needed for such a comprehensive approach may pose a problem.

Solow proposed a transcendental ! like approach to the incorporation of technological change. Following his approach, a simple model would be

†23.11 $$y = A\, x_1^{a} x_2^{b} e^{rT}$$

where T is a measurement thought to represent technology, such as time, e is the base of the natural log, and r is the associated coefficient.

Such a model would allow for variable rates of change in marginal products as a result of the new technology. The function is readily transformed to its natural logarithms and estimated by ordinary least-squares regression. This approach is applicable in instances where it is not readily apparent which specific inputs are affected. A similar approach would be to use the transcendental function

†23.12 $$y = a x_1^{\alpha_1} x_2^{\alpha_2} e^{\gamma_1 T x_1 + \gamma_2 T x_2}$$

where T is the technology measure. The values for $(_1$ and $(_2$ would indicate the extent to which the new technology favors input x_1 or input x_2.

Approaches exist for dealing with technology in an agricultural production function. However, a major problem remains in that the variable technology is often difficult if not impossible to measure. Exceptions exist in instances where the specific technology is readily identifiable.

For example, successful studies have been conducted when the technology is similar to the development of hybrid corn, high yielding rice varieties in international development, or a mechanized tomato harvester. The kind of technological change that usually takes place in agriculture is more gradual and less dramatic. Sometimes agricultural economists simply ignore gradual technological change and hope that the gradual changes associated with a general technological improvement do not significantly affect research results.

23.3 Conceptual Issues in Estimating Agricultural Production Functions

The estimation of agricultural production functions from survey data collected from farmers has been a very widespread activity by agricultural economists. A common approach might be to survey 100 farmers with regard to the quantities of seed, fertilizer, chemical, and other inputs used, and then attempt to estimate a single production function using the 100 farmers as individual observations in the data set. This research approach is becoming very popular in studies conducted in developing countries.

Major problems exist with this research approach. Some of the problems are readily apparent, while others are more subtle but of no less importance. One readily apparent problem stems from the lack of controlled experimental conditions. It may rain on one surveyed farmer but not on another. Soil conditions may vary from farm to farm, and managerial skills may differ from farm to farm. Yet a single production function will be estimated for all farms in the sample. Most researchers recognize that the lack of controlled experimental conditions represents a major problem with this approach to estimating agricultural production functions, and attempt to take steps to control for factors such as soil type and weather conditions.

Less well recognized but no less important are the problems associated with the behavioral objectives of the manager whose farm is part of the data set. Only one production function is to be estimated from the entire data set. Agricultural economists like to assume that farmers are profit maximizers or, as an alternative, seek to maximize revenue subject to a cost constraint. Prices for both inputs and outputs are largely given, and on a cross-sectional basis do not vary significantly from farm to farm.

If a single production function applies to all farms (an assumption basic to the estimation of the production function with farms as observations), information is complete, input and output prices are fixed and the same for all farms, and farmers maximize profit, then all farmers should have found the point where *VMP* equals *MFC*. The data from which the production function is to be estimated do not consist of a series of points but rather, a single point. All farmers are using the same quantities of inputs and producing the same yields. To the extent that farmers are not all observed to be operating at the same point, one or more of the assumptions have broken down. Either the farmers do not know how to or cannot maximize profits, the same production function does not apply to all farmers, or input and output prices are not constant.

Suppose that farmers are not globally maximizing profits, but rather, seek to maximize revenue subject to a cost constraint. In this case, all farmers would be operating on the same expansion path, but larger farmers would be operating closer to the point where profits are globally maximized, where 8 equals 1. Again, the basic assumption of the analysis is that the same production function applies to all farmers in the data set. If the production function is homothetic, the expansion path is linear or has a constant slope, and input prices are constant. Each farmer's input bundle differs in size from the input bundle owned by the other farmers in the data set, but everyone's input bundle contains the same inputs in the same proportions.

If agricultural economists collect data from survey farms, farms with large outputs will use large amounts of fertilizer, chemicals, and other inputs. Smaller farms will use smaller amounts of fertilizer, chemicals, and other inputs. However, the proportions of each input in each bundle remain constant. When the statistical research is conducted, the agricultural economist discovers that the data series for the individual inputs are very highly correlated with each other. A large farmer using lots of fertilizer will also use lots of chemicals and other inputs; a small farmer uses small amounts of fertilizer, chemicals, and other inputs. This correlation leads to multicollinearity problems which, if severe enough, make it impossible to estimate the production elasticities for the individual inputs.

What is seldom recognized is that such problems should occur as a direct result of the assumption that farmers would like to be on the expansion path. To the extent that the individual input categories are not perfectly correlated with each other, either a single production function does not apply to all farmers, input prices vary from farm to farm, or farmers are not on the expansion path. The breakdown of any of these assumptions is not very comforting to those agricultural economists who understand marginal theory in a purely competitive environment.

Agricultural economists thus find themselves in a very difficult position. To the extent that the results of the analysis are stable enough to provide statistically significant estimates of individual production elasticities, one or more of the theoretical assumptions underlying the analysis has, to a degree broken down. To the extent that individual production elasticities are unobtainable, the theoretical assumptions hold. However, this is of little consequence to agricultural economists in need of specific estimates of *MPP*'s and production elasticities. (See Doll for additional discussion of this problem.)

One approach to deal with this problem would be to abandon attempts to estimate agricultural production functions from nonexperimental farmer-generated cross-sectional data. Reliance might instead be placed solely on data obtained under controlled experimental conditions in agricultural experiment stations or other laboratory facilities. In the United States, such data do represent an important basis for the estimation of agricultural production functions. The problem here is that such data do not entirely reflect what is happening in an actual farm setting.

A gap exists between results obtained at an experiment station and on the farm. Experiment station yield trials may utilize a hand harvest not feasible or possible on large acreages on a farm. In the United States, as in most developed countries, the gap between experiment station and on ! farm results is not that large, and perhaps adjustments could be made to take the gap into account. In developing countries the gap can be very large indeed, and agricultural economists working in these countries almost certainly need to know exactly what is happening on the farms themselves.

23.4 Concluding Comments

This chapter was called "Frontiers in Agricultural Production Economics Research" for a reason. The earlier chapters largely fit together as a neat package. Problems were proposed, models developed and analyzed, and solutions obtained. Unlike the earlier chapters, in this chapter problems are proposed and possible models presented, but no simple and neat solutions have been presented.

The issues presented in this chapter were chosen because they represent examples of highly significant and as yet unresolved problems confronting agricultural production economists. Much of agricultural economics research deals directly with problems such as these, and work on such problems is challenging. It is the author's hope that this book has stimulated both an interest in and an appreciation for the work of agricultural economists.

Problems and Exercises

1. What is management?

2. How might management be measured?

3. Outline alternative ways in which management might be incorporated into a production function. Explain the consequences of each approach.

4. What is new technology?

5. How might new technology be measured?

6. Is a time variable a proxy for new technology? Explain.

7. Outline alternative ways in which new technology might be incorporated into an agricultural production function. Explain the consequences of each approach.

8. Draw alternative isoquant maps representing the probable alternative consequences of new technology.

References

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