

# Economic Analysis of Agricultural Investments

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**Abstract.** The purpose of this paper is to introduce a modification of a standard four input production process where energy is used in an inefficient way due to partly unnecessary waste of energy. The changes in production efficiency investigated using stochastic frontier methods, show declining technical efficiency in livestock production and especially low marginal contribution of labor inputs. The number of workers, size of farm, and distance from nearest city are related to efficiency in agricultural production. It is well known that results from an environmental policy in response to global climate change are quite sensitive to the assumption on the rate of energy efficiency improvements. However, technical progress is traditionally considered as a non-economic variable in economic policy models. It is exogenous in most policy evaluations as well as in the theory of environmental economics.

**Keyword:** agriculture resources, agriculture management, financial instrument for agriculture production process, technical efficiency, frontier production function.

**JEL Code:** N50, R15

## 1. Introduction

Inputs for agricultural production can be distinguished by their cost relevance and their infrastructural requirements. Some inputs like grain seeds or granular mineral fertilizer in bags have lower requirements and are fairly easy to handle, others like liquid chemical pesticides have higher requirements particularly in terms of handling and user knowledge in order to avoid environmental and safety hazards.

Agricultural equipment, implements and machinery are among the most demanding of agricultural inputs. Mechanization inputs usually represent a fairly high share of investment capital of a farm, their correct use can be complicated and requiring high level of knowledge and abilities and they usually need a complex infrastructure to be operated in a sustainable way. This infrastructure includes repair facilities, spare and wear part supply, as well as a supply of other inputs for their operation like fuel and lubricants.

## 2. Agricultural input in production process

Capital consists of all the equipment, structure, and machinery used for production. Capital represents outcomes of previous production activities that are embodied in some assets relating to present production activities. Generally, capital is utilized with viable inputs, labor, energy and fertilizers, that are consumed by the production process. Producers may purchase services of capital goods or they may own capital assets that would be evaluated differently in their accounting documents. Capital is measured by the value of the assets that are used as capital

goods. In each period there is a cost associated with the use of capital goods. First, it includes the cost of physical depreciation as well as the periodical costs for the resources that were used in the capital investment (interest costs).

One difficulty in measuring labor comes from the differences in quality between different individuals. Generally, there can be different wage rates according to the quality of labor services provided. An important concept is human capital. Knowledge acquired through training and education in the past is a determinant of productivity in the present. Compensation for workers combines payment for the raw labor services as well as a return for their human capital.

As labor, land is not a homogeneous input. Land quality varies depending on location, physical characteristics, etc. There are different mechanisms for payment of land services including rental fee, sharecropping, etc. Moreover, quality of land may affect the effectiveness of new technologies.

Pesticides are damage control agents. Their productivity depends on the environment, the pest situation, and the product.

The value of water depends on its use, quality, and location. Each input has unique features that may be essential in modeling behavior at the farm level. As the analysis become more aggregated, generic modeling is more relevant.

The modeling analyze problems of water and pesticides will demonstrate how some of the basic biological or physical properties of water and pest control affect the specifics of the modeling of the production process, the nature of choices that are applied, and the type of outcome that we will observe.

The new approach really starts after the need for agricultural mechanization input supply in a country has been identified, in quantitative and qualitative terms assessed and a donor has agreed upon the amount of money. In the recipient country then persons or structures are identified that qualify as commercial distribution channels for the required inputs. Important is that they have a long term interest and commitment as well as the infra-structural, economical, technical and personal characteristics to successfully initiate and run the operation of an agricultural machinery dealer including the after sales service.

It is naive to think that once a new technology is introduced it is adopted immediately. The process of adoption is time consuming; it took about 40 years for a complete adoption of the mechanical tractor and about three to five years to complete the adoption of the tomato harvester. Other types of technological adoption the right use of fertilizers and the use of new varieties also take time and follow interesting patterns.

The study of diffusion processes has concentrated on two areas: diffusion of durable goods (such as television sets) and diffusion of high yield varieties by farmers. The rate of adoption is an increasing function of time during which the new innovation has been available.

Pesticides are chemicals used in controlling agricultural pests. There are three major classes of pesticides: insecticides, fungicides, and herbicides. The use of pesticides in agriculture presents some interesting aspects to be considered:

- they need to be chemically updated over time as pests build resistance;
- there are adverse human and animal health effects associated with pesticide use, as well.

The adverse human health effects of different types of pesticides depend on the similarity between human or animal biology and the biology of the target pest; insecticides, for example, are generally worse for human health than fungicides.

Herbicides: from 1965 to 1980, growth in the relative price of labor increased the use of herbicide as a factor of production. This occurred because herbicide use is a substitute for labor. During the 1980s, lower agricultural commodity prices and reduced crop acreage led to an overall reduction in herbicide use.

Insecticides: During the 1970's, an increase in energy prices led to a reduction in insecticide use.

Fungicides: Fungicide use has remained relatively stable over the past 30 years, although recent legislation banning the use of carcinogenic chemicals in the Delaney Clause will soon outlaw many fungicides (and several popular insecticides and herbicides).

Obviously, there are costs associated with pesticide application. If the total damage from pests is less than the social cost associated with a single application of a pesticide to a field (including Marginal External Cost MEC), then the welfare maximizing level of pesticide use is zero. Note that this implies toleration of some pests in the field as well as toleration of the associated pest damage, such as less visibly appealing fruits and vegetables.

The notion of production function is applied for different levels of aggregation. We can speak about the production function of an individual process (a production function of wheat in one field), production function of producers (a production function of wheat producers with several fields); production function of an industry producing the same product; production function of a sector that includes several industries; and an economy aggregate production function. Aggregation may require a redefinition of input and output, especially for conceptual analysis, as one has to reduce the number of variables to a bare minimum to illustrate some concept without having an extremely complicated analysis. Even empirical analysis may require reducing the dimensionality and aggregation. One question is: under what condition would aggregation become meaningless and the results not useful?" The biggest controversy has been related to economy-wide production functions. One of the most important areas of research after World War II were attempts to understand the process of economic growth. Kuznets established a national accounting data on output, capital, and aggregate labor. Many researchers, most notably Robert Solow, developed a neoclassical growth theory to analyze these data. The growth literature that Solow developed was very important during the 1960's and early 1970's, and it spawned another body of literature that attempted to explain the process of innovation. The first critical seminal article in the literature on innovation and growth was an article on learning by doing by Kenneth Arrow. The article was published in 1967. There has been a resurrection in the mid-1980's because of the works of Lucas and, in particular, Paul Romer, who introduced a new concept: endogenous growth. Romer's work has become an important element of microeconomics, but we will return to our discussion of production and, in particular, the Cambridge controversy that led to the putty-clay model which is our subject of interest. The Cambridge controversy was a debate between economists in Cambridge, Massachusetts, headed by Robert Solow and Paul Samuelson, proponents of the neoclassical production function and neoclassical growth theory, and economists in Cambridge, England, headed by Joan Robinson, Piero Sraffa, and Luigi Pasinetti. Neoclassical growth theory assumes the existence of an aggregate production function where national output is produced by aggregate labor and aggregate capital stock. It also assumes that there is an endogenous process of technological change that increases input productivity overtime. Solow estimated an aggregate model of economic growth of the form:

$$Y_t = A L_t^a K_t^b e^{nt},$$

where:

$Y_t$  = aggregate output

$L_t$  = aggregate labor

and

$K_t$  = aggregate capital.

His model has had a good statistical fit and  $n$ , the time coefficient, was found to be quite substantial, indicating the importance of technological change. The model assumes that the economy has a stock of capital,  $K_t$ , which is augmented by investment  $I_t$ , but may decline due to depreciation. This approach suggests measuring capital by dollar units and assumes that capital goods are malleable. The malleability of capital seems unreasonable to the Cambridge, England, economists. The English economists argued that there is much specialization of capital goods |a tractor cannot print books. Therefore, the notion of aggregate capital is meaningless, and policies based on assumption of smooth substitution between capital and labor may be wrong. The Cambridge controversy was a debate about the formulation of production and microeconomics. Both groups have valid points. The basic idea of assessing aggregate productivity in the economy taken by the Cambridge, Massachusetts, scholar was viable. The effort they started led to important results, and growth theory is a very important area of research. However, the England group was correct in saying that higher capital expenditures do not necessarily mean more exibility in production since capital goods are limited in theft uses. One of the important elements in Romer's new model is the explicit recognition of the role of specialized capital goods and the limited extent of malleability that capital goods have. The Cambridge controversy can be summarized succinctly as the argument about the magnitude of the elasticity of substitution between capital and labor. The neoclassical economists assume that the elasticity of substitution is quite high and the English economists assume that it is very low and relationships are converging to a fixed proportion production function The compromise was presented in "putty clay" models.

Putty-clay models were introduced by Johansen and Salter. They separated between micro and macro and ex ante and ex post production functions. A micro production function is the production function of an individual producer. A macro production function is a production function of an industry. One challenge is to develop aggregation procedures to move from micro to macro relationships. The ex ante choices are the putty stage, before the shape of the final machine is determined. Ex post choices are at the clay stage where the equipment is well formed and limits the exibility of choices. The ex ante production function is used for long-run choices before investment takes place and where the capital level is exible. An ex post production function reects choices when capital outlay is completed and capital is less exible. Putty-clay models assume that, at the microlevel, ex ante production functions are neoclassical and have positive elasticities between capital and other inputs, but ex post functions have fixed proportions and zero elasticity of substitution. Thus, the putty-clay models separate between

1. micro ex post production function,
2. micro ex ante production function,
3. aggregate ex post production function, and
4. aggregate ex ante production function.

Salter introduced a graphical presentation that is very useful for explaining the putty-clay model. His model is dynamic, and he looks at determination of prices and investment at a given period. At the start of the period, the industry has a distribution of existing production units that were built in previous years. Every year entrepreneurs make ex ante decisions about new capital. In a later lecture, we will study in detail the determination of capital and labor costs of a new technology for a given moment in time; however, here we will make some

general assumptions about the trend in capital costs and variable costs over time. Every year entrepreneurs determine the cost of a new capital good, its production technology, and its production capacity. Salter assumes that technology has constant returns to scale, and the cost of variable inputs such as labor increases over time relative to capital. Technological change and the relative price of labor results in new technology with lower variable costs but may have slightly higher annualized fixed costs. Suppose we are at the beginning of period  $t$ . The industry inherits capital that was built in previous periods. Let  $C_{t-j}$  be the productive capacity of facilities that were built  $j$  years before  $t$ . We can refer to these machines as vintage  $t-j$ , and  $C_{t-j}$  is the productive capacity of vintage  $t-j$ . Productive capacity is the maximum output that these machines can produce if they are utilized. Let  $V_{t-j}$  be the variable input cost per unit of output of machines of vintage  $t-j$ . Thus, at the beginning of the period, the industry has output supply of an existing plant that is a step.

### 3. The economics of land-quality augmenting input

The model use following symbols:

$y$  = output per ha;

$x$  = effective input per ha;

$a$  = applied input per acre;

$i$  = application technology indicator;

$i = 0$  for traditional technology;

$i = 1$  for modern technology

$f$  = land quality

$0 < f < 1$

$f$  measures input use efficiency of traditional technology on soil

$y = f(x)$  is production function, with  $f'(x) > 0$  and  $f''(x) < 0$ .

$h$  = input efficiency function;

$h$  = fraction of input consumed by crop with technology  $i$  and land quality  $f$ .

$P$  = output price

$A$  = water price

$K_i$  = per ha cost of technology  $i$  with  $k_1 > k_0$

The optimization problem faced by a farmer when choosing the technology, is:

$$\text{Max}_i \sum_{i=0}^1 (P f(h x_i) - A x_i - K_i)$$

Experience in the past has shown that the traditional approach of a centralized procurement and supply of agricultural mechanization inputs has proven not to be sustainable. It often has led to undesirable side effects in social structures and is counter-productive for the development of independent sustainable supply structures. Economical losses for the countries and farmers were often a consequence and were counterbalancing the obvious savings achieved by tendering large quantities of similar items.<sup>4</sup>

The problem of optimization production function :

$$\max_x f(x);$$

$x$

$$x \geq 0, \text{ when } f \text{ is concave.}$$

Optimal value,  $x_1$  of function  $f$ , is  $f'(x_1) = 0$ . Maximum is global in condition  $f''(0) < 0$ .<sup>7</sup>

$$\max_x f(x),$$

$x$

in initial restriction condition  $g(x) \leq b$ ;

$$x \geq 0.$$

$$g(x)+z=b, \Rightarrow z=b-g(x), \text{ unde } z \geq 0.$$

Optimization of function  $f$  became:

$$L = \max_{x,z,\lambda} f(x) + \lambda [ b - z - g(x) ]$$

**Study of case:** A vegetable farm with 50 corn ha have 8 t chemical fertilization. The production function specific on climatic and agrochemical farm condition is:

$$y = 4000 + 30 x - 0.0728 x^2, [\text{kg/ha}]$$

$x$  = nitrogen chemical fertilization, kg.

It is considered a 0.5 \$/kg trade price and 0.5 \$/kg administration cost of chemical fertilization. Fixed production cost is evaluate at 1500 \$/ha.

The technical production function it is a model used to calculate optimal fertilization quantity ( $x_t$ ), from tehcnical point of view:

$$y = 4000 + 30 x_t - 0.0728 x_t^2, [\text{kg/ha}]$$

$x_t$  = kg de azot.

The optimal value,  $x_t$  represent maximum of function  $y$ , it is find with  $y^1(x_t)=0$ , and these is global maximum of function  $y$ , in condition  $y^2(0)<0$ .

$$dy/dx_t = 0$$

$$30 - 2 \cdot 0.0728 x_t = 0$$

$$x_t = 30 / 0.1456 = 206 \text{ kg}$$

The maximum production:

$$y_{\max} = 4000 + 30 \cdot 206 - 0,0728 \cdot 206^2$$

$$y_{\max} = 7091 \text{ kg/ha};$$

The production value in case of fertilization with optimum economic dose:

$$V_t = p \cdot y_{\max};$$

$$V_t = 0,5 \cdot 7091 = 3545,5 \text{ \$/ha};$$

The production cost:

$$C_t = C_f + C_v;$$

$$C_v = 0,5 x_t;$$

$$C_t = 1500 + 0.5 \cdot 206 = 1603 \text{ \$/ha};$$

The profit in these case:

$$Pr_t = V_t - C_t;$$

$$Pr_t = 3545,5 - 1603 = 1942,5 \text{ \$/ha}$$

The profit function,  $f(x)$  is calculated on technical production function model:

$$f(x) = V - C$$

$$V = 0,5 y(x);$$

$$C = C_f + C_v;$$

$$C_v = 0,5 x;$$

$$f(x) = 0,5 y(x) - C_f - 0,5 x;$$

where:

- $f(x)$ , profit function in relation with fertilization allocation quantity;
- $V$ , production value;
- $C$ , production cost;
- $C_f$  fixed cost;

-  $C_v$ , variable cost in relation with fertilization allocation quantity.

The optimal economic fertilization dose ( $x_e$ ) it is calculated with profit function, assess maximum condition:

$$\begin{aligned}f'(x_e) &= 0 \\0,5 \, dy/dx_e - 0,5 &= 0 \\30 - 2 * 0,0728 \, x_e &= 1 \\x_e &= 29/0,1456 = 200 \text{ kg}\end{aligned}$$

The production in these case is:

$$\begin{aligned}y(x_e) &= 4000 + 30 * 200 - 0,0728 * 200^2; \\y(x_e) &= 7088;\end{aligned}$$

The production value in case of fertilization with optimal economic dose is:

$$\begin{aligned}V_e &= p * y(x_e); \\V_e &= 0,5 * 7088 = 3544 \text{ \$/ha};\end{aligned}$$

The production cost in these case:

$$\begin{aligned}C_e &= C_f + C_v; \\C_v &= 0,5 \, x_e; \\C_e &= 1500 + 0,5 * 200 = 1600 \text{ \$/ha};\end{aligned}$$

The profit in these case is:

$$\begin{aligned}Pr_e &= V_e - C_e; \\Pr_e &= 3544 - 1600 = 1944 \text{ \$/ha}\end{aligned}$$

The Matlab graphical representation of profit function ( $f$ ) and technical production function ( $y$ ) is realized with program:

```
close;clear;
for i=0:1:500,
j=i+1;
x(j)=i;
y(j)=4000+30*x(j)-0.0728*x(j)^2;
f(j)=0.5*y(j)-1500-0.5*x(j);
end;
subplot(211);
plot(x,y);
grid on;
title('Technical production function');
xlabel('Fertilization dose, x [kg]');
ylabel('y [kg/ha]');
subplot(212);
plot(x,f);
grid on;
title('Profit function');
xlabel('Fertilization dose, x [kg]');
ylabel('f [$/ha]');
```

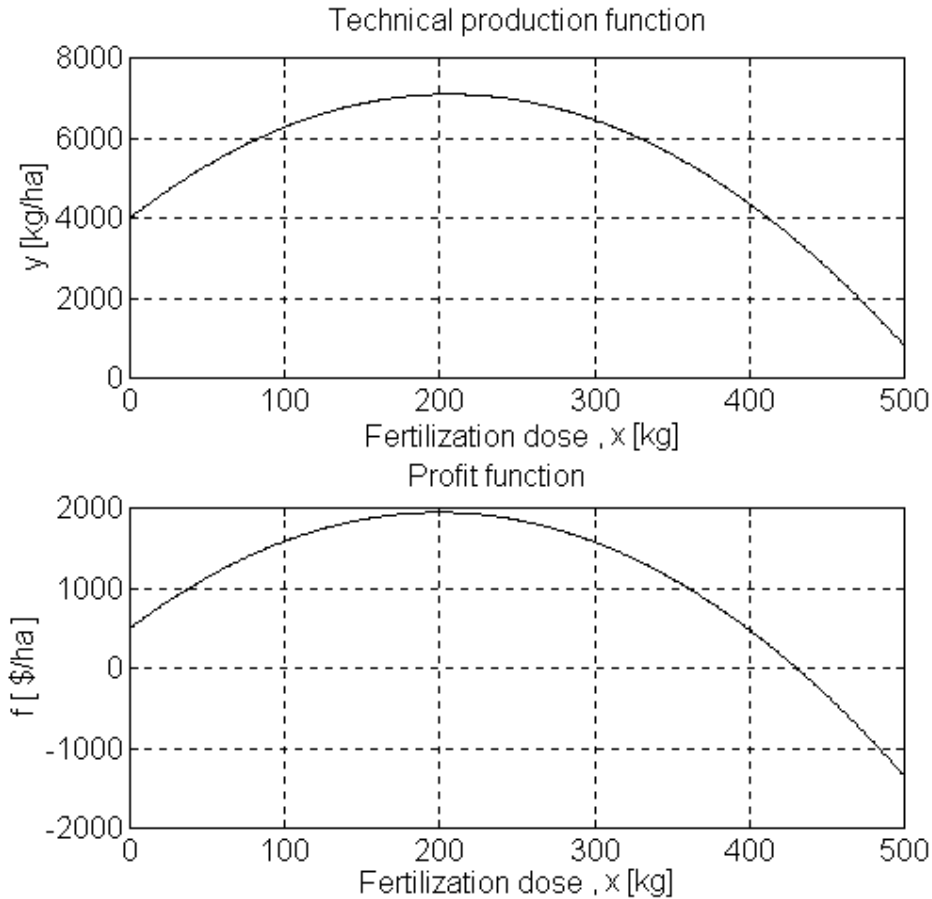


Figure nr. 1. Graphical representation of profit function and technical production function

### Comparative analysis of fertilization variants

Indicator	Technical optimal	Economic optimal	Economic – technical optimal differences
<i>Fertilization dose, kg/ha</i>	206	200	-6
Production, kg/ha	7091	7088	-3
Production value, \$/ha	3545,5	3544	-1,5
Variable cost, \$/ha	103	100	-3
Profit, \$/ha	1942,5	1944	-1,5-(-3)=1,5

The comparative analysis of the two variants reflect a profit increase in case of economic optimal dose (with 1,5 \$/ha), determined by reduce of variable administration fertilization cost more than reduce of production value (-3 \$/ha comparative with -1,5 \$/ha).

Optimal economic dose enable maximum profit at ha.

The necessary of economic fertilization dose is:

$$N_e = S x_e = 50 * 200 = 10 \text{ t};$$

The available fertilization resource is  $R = 8 \text{ t}$ .

The optimal fertilization variant is determined in this case with Lagrange function model:



$$L = \max_{x,z,\lambda} f(x) + \lambda [ b - z - g(x) ]$$

where:

- $f(x)$ , profit function in relation with fertilization allocation quantity;
- $x$ , fertilization dose use in production process, kg;
- $\lambda$ , Lagrange parameter;
- $b$ , total fertilization quantity use in production process;
- $g(x)$ , represent fertilization restriction, limited farm quantity;
- $z$ , auxiliary variable, which enable the transformation of fertilization restriction in equation.

$$\begin{aligned} f(x) &= V - C \\ V &= 0,5 y(x); \\ C &= C_f + C_v; \\ C_v &= 0,5 x; \\ f(x) &= 0,5 y(x) - C_f - 0,5 x; \end{aligned}$$

where:

- $f(x)$ , profit function in relation with fertilization allocation quantity;
- $V$ , production value;
- $C$ , production cost;
- $C_f$ , fixed cost;
- $C_v$ , variable cost in relation with fertilization allocation quantity.

$$\begin{aligned} y(x) &= 4000 + 30 x - 0,0728 x^2, \text{ [kg/ha]} \\ f(x) &= 2000 + 15 x - 0,0364 x^2 - 1500 - 0,5 x; \\ f(x) &= 500 + 14,5 x - 0,0364 x^2; \end{aligned}$$

The Lagrange function in this case is:

$$L = \max_{x,z,\lambda} [500 + 14,5 x - 0,0364 x^2 + \lambda ( 8000 - z - 50 x ) ];$$

The maximum condition of Lagrange function is:

$$\begin{aligned} dL/dx &= 0; \\ dL/dz &= 0; \\ dL/d\lambda &= 0; \end{aligned}$$

The partial derivation of Lagrange function is:

$$\begin{aligned} 14,5 - 0,0728 x - 50 \lambda &= 0; \\ \lambda &= 0; \\ 8000 - z - 50 x &= 0; \end{aligned}$$

The optimal solution from equation system is:

$$x = 199$$

#### 4. Conclusions

Some of the basic points that will be emphasized include:

1. Some decision variables are discrete and others are continuous. Firms have to make simultaneous choices about the nature of technology |whether they will use drip or sprinkler irrigation or biological or chemical control. These choices are dichotomous choices and decision variables can assume values of 0 and 1. The types of choices are also dealt by technology adoption models. Other choices are with respect to the value of a given variable,

for example, how much water should be applied. The variables in this case are determined from a continuous set.

2. There is heterogeneity in production. Producers operate under varying sets of circumstances that may result in different outcomes. The causes for variability may be differences in environmental conditions (land quality), human capital, and physical capital.

3. There are differences in long-run and short-run choices. Short-run choices entail much less exibility than long-run choices. However, the outcome of short-run choices are much easier to predict.

4. Aggregation is a challenge in both short-run and long-run analysis. To obtain meaningful predictions of production choices and market outcomes under heterogeneity, meaningful aggregation procedures are essential. Modeling production processes is essential for developing realistic policy analysis frameworks. In all of the modeling, one needs to investigate the implications of the approach for policy purposes.<sup>5</sup>

Key concepts are:

- Notions of present value
- Internal rate of return
- Cost of capital
- Depreciation
- Obsolescence
- Ex ante vs. ex post production functions
- Micro vs. macro production functions

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