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Impact of technological advance on farm family income inequality

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IMPACT OF TECHNOLOGICAL ADVANCE ¹²⁹
ON FARM FAMILY INCOME INEQUALITY

by

Yoichiro Kawasaki

A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
MASTER OF SCIENCE

Major Subject: Agricultural Economics

Approved:

Signatures have been redacted for privacy

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I. INTRODUCTION

A. Objectives of Study

Recent development in technology has caused widespread changes in the agricultural sector. The effects on output prices, income redistribution between farm and nonfarm sectors, and the implication for farm resource adjustment have been widely studied. Relatively little attention, however, has been paid to the effect on another aspect of technological change in agriculture, i.e. personal income distribution among farm families.

With the achievement of a higher level of per capita income, society has become more concerned with the personal distribution of income. Poverty amidst general affluence has received increasing attention by sociologists, economists, and public policy makers. Income distribution among farm families, to which rural poverty is closely related, is undoubtedly one of the more urgent problems in contemporary society.

Technological change tends to redistribute income among farm families within the farming sector as well as between farm and nonfarm sectors. Redistribution takes place (1) among farms producing different products, (2) among farms in different geographical areas, and (3) among farms of different sizes. Although all of these redistribution effects have important implications for rural poverty, resource readjust-

ment and so forth, this study is limited to the income distribution among farms of different size.

It appears that there exists a mechanism through which technological change widens income inequality among farm families. Undoubtedly, there also exist certain forces that offset the income inequality increasing effect of technological change. The movement of income inequality is determined by balance between these two forces. The major objective of our study is to identify and analyze these income inequality increasing forces associated with technological change.

B. Main Hypothesis and Procedure of Analysis

Our main hypothesis in this study is as follows: Technological change in U.S. agriculture tends to increase the inequality of income distribution among farms.

The U.S. agriculture has experienced tremendous changes in technology. Society's knowledge regarding the ways in which production is performed has been rapidly increasing. This is largely a result of a steady flow of public investment in research and development, which started a century ago. It is also a product of research activities performed by private industry in recent years.¹

¹"An important source of new knowledge has been the USDA and the land grant colleges, which are supported by public investment. This investment has extended over a century, but it has been largest and most effective since about 1910. Research and extension education were not supported at a high level until somewhat later... In terms of changing the (footnote continued on following page)

As a result of increased knowledge regarding technology and its application to agricultural production, resource productivity in agricultural industry has rapidly increased. Crop yield per acre and livestock production per animal have increased, the size of farm firms has been expanded, labor productivity has had a substantial increase, and many other improvements have taken place.

Technological change appears to have had an important side effect in the agricultural industry, namely, an increase in the inequality of income distribution among farm families.¹

(footnote continued from previous page) demand for inputs and the supply of commodities, perhaps no other set of forces has been so influential in the years since 1920. However, private industry now makes an immense contribution to the growth in agricultural technology. This growing investment by private business is encouraged especially at high stages of economic development, where the major portion of farm inputs is purchased from nonfarm sources. Private firms then have a much larger market for inputs in agriculture as compared to the situation at lower stages of economic development in earlier years. Future economic development will be associated with continued efforts of private sector to extend knowledge of agricultural production" (32, pp. 53-54).

¹In addition to the increased inequality of income distribution, technological change appears to have side effects which are not necessarily desirable to the industry or the whole society. Mansfield describes the problems arising from technological change as follows:

"Unfortunately, there is also a more somber side to technological change. Advances in military technology have made possible the destruction of mankind on an unprecedented scale, modern technology has resulted in air and water pollution, the closing of plants made obsolete by technological change has thrown whole communities into distress, and the technological revolution in agriculture has contributed to serious problems, both urban and rural. (footnote continued on following page)

The process in which the benefit of technical improvements accrues to individual farms, differences in the farms' response to technological change, price changes due to possible output increase, differences in capacity to invest in new, improved inputs, etc., appear to influence farm income in such a way that the large and rich farms obtain a greater benefit of technological change than the small and poor farms. This study will examine various factors which cause differential income effects among farms. The analysis will be made as following:

First, the nature of technological change itself and its differential effect on farm income among families are examined. If a technical improvement is made both in the large and the small farms, an income increase due to the improvement may differ between them. This is so because they have different size of factor inputs.

Second, the large and the small farms may respond to the improvement differently. In other words, there may be considerable difference in the time when the improvement is actually made in these farms, even though both farms benefit from it (if it is adopted).

Major factors which may contribute to this differential

(footnote continued from previous page) Although most people would agree that, on balance, technological change has been beneficial, no one would claim it has been costless" (47, p. 3).

adoption behavior are as follows: (1) The entrepreneurs' information search activities contribute to more rational decision making with respect to the adoption of the improved technology and to reduced uncertainty over the expected return therefrom. Differences in their participation in information search, in their capability to analyze it and to reach adequate decisions on its adoption are, therefore, the important determinants of the time of its adoption.

(2) Families which have different levels of income may respond to the same uncertainty situation differently. The adoption of technical improvements involves considerable risk and uncertainty. If some farms are more willing to run a risk of investing in a new income earning opportunity opened up by improved technology than other farms, the time when the improvement is actually made will differ between these farms.

(3) Difference in family income may affect their saving and investment behavior through different preference they have with respect to a choice between present and future consumption. Since making technical improvements involves new investment in most cases--for example, information search activities are viewed as one form of investment as discussed in chapter III, and new machinery and equipment may require a substantial amount of new investment--farms which are able to and willing to invest more will adopt these improvements more readily than farms which are not.

Third, the time of adoption has an important effect on prices the farms receive for their outputs. As an increasing number of farms adopt the improvement, production increases and price goes down unless demand for the product increases. While the early adopters reap the full gain of the improvement because few have adopted it and price has not fallen, later adopters gain much less or not at all, depending on the amount of price decline. If demand is price inelastic, the larger output will sell for less total revenue. Farmers who have not adopted the improvement are placed in a more unfavorable position. If, therefore, the farmers' adoption behavior is correlated with their income and size, the changes in prices have an important effect on income inequality.

Fourth, another feature of technological change is its disequilibrating effect on the farm firm. For example, introduction of the corn picker has displaced labor employed in corn production on the farm. Unless this released labor finds profitable alternative employment, the benefit of the improvement is not fully realized. The expansion of farm size is the most effective means of re-employing this released labor within the farm. If there is difference among farms in capacity to expand the size of operation, farm growth will be another factor which affects income inequality.

There appear to exist several factors that determine the rate of farm growth: (1) A difference in farm income

results in a difference in savings behavior which, in turn, produces a difference in the amount of investment funds available from family savings. (2) Differences in the entrepreneurs' risk bearing behavior and their ability in making the accurate assessment of cost-return relationship, which contributes to a reduction in uncertainty associated with the new investment, may have differential effects on the availability of borrowed capital. (3) Difference in managerial ability among entrepreneurs may cause wide difference in the rate of growth because farm firm growth involves a substantial amount of additional entrepreneurial activities compared with their activities which are not related to growth.

C. Review of Literature

This section is devoted to a short review of the existing research data on personal income distribution in the farming sector, and its change in relation to technological advance. Although there are a number of studies on income distribution in the whole economy and they are no less important to our purpose,¹ our attention here is focused on studies directly related to the income of farm families.

¹Miller (49) and Morgan and others (50) give overall views of personal income distribution, the distribution of income components, and the trend in the distribution in the United States. More recent and detailed analyses including the theoretical treatment of income distribution, its historical surveys, etc. are found in Soltow (63).

1. Income distribution among farm families

Several studies have examined the personal distribution of income in agriculture. They are classified into two broad categories (1) statistical studies comparing income distribution in the farming sector with that in the nonfarm sector, or to examine the historical trend of inequality (Grove, 26; Boyne, 8) and (2) those trying to explain geographical differences in income inequality (Bryant, 10; Coffey, 12; Gardner, 24).

Studies in the first category are conveniently summarized in Table 1.1. Boyne states, "(during the post-war period) the inequality of the income distribution for farmer and farm manager families was greater than for any other occupational groups identified by CPS income surveys. The concentration declined by 15 percent over the period and in recent years has been almost equal to that of other self employed groups" (8, p. 1223).

2. Change in income distribution due to technological advance

Lack of data is impressive in the field of our concern, i.e., relationship between technological advance and income distribution.¹ A part of it is explained by the fact that most of those studies dealing with income distribution drew

¹Bonnen (6, p. 419) pointed out the similar situation of data shortage with respect to the distributional impacts of public programs.

Table 1.1. Gini ratio of the distribution of total money income for selected groups in the United States: 1948 to 1963^a

Year	Farmer and farm-manager families	Farm-laborer and foreman families	Rural farm families	All families with an employed head
1948	.550	.359	.476	.348
1949	.532	.326	.488	.356
1950	.523	.361	.476	.354
1951	.506	.430	.460	.337
1952	.496	.462	.478	.345
1953	.515	.400	.486	.326
1954	.508	.351	.477	.334
1955	.507	.400	.451	.337
1956	.468	.389	.448	.330
1957	.450	.413	.445	.322
1958	.462	.369	.434	.324
1959	.464	.394	.456	.325
1960	.461	.428	.456	.335
1961	.454	.376	.448	.342
1962	.452	.362	.431	.328
1963	.468	.400	.436	.323

^aSource: (8, p. 1221).

their data from such government surveys as Census of Agriculture, Census of Population, and Current Population Survey. Since these surveys were designed to collect information on the distribution of total money income of farm families, the income of farm origin was not separated from other components of family income. Since the data were not classified by farm and farm family characteristics, it has not been able to relate income to characteristics associated with technological

advance. The result is that only a few isolated studies based mainly on indirect reasoning rather than direct statistical evidence have been made so far. They are summarized as follows:

Heady (29) states that income transfer takes place (1) between producers and consumers, (2) among producers of different commodities, (3) among producers in different areas, and (4) due to changes in the capitalized value of wealth.

Kendrick (42, pp. 1071-1072) argues:

" . . . the labor share of national income has risen, and the share of property compensation has fallen. Since property income went largely to upper income groups, the decline in its relative share has contributed to greater equality of income distribution. I attribute this development to technological change, since without it capital accumulation would have been slower (probably no greater proportionately than growth of the labor force), and the real wage rate would not have exhibited so rapid a relative change.

"Secondly, technological advance has increased the relative demand for more highly skilled and professional personnel, while its contribution to real income has made possible the increasing investment in education and training required to effectuate a gradual upgrading of the labor force. The increased relative supply of more highly trained and educated members of the labor force has, in turn, contributed to a narrower dispersion of wage and salary rates."

Referring to the low income farms' reaction to technological change, Hendrix states (36, p. 74):

"Available evidence indicates . . . that the small farms and to a lesser extent, small family farms, are being by-passed in the process of mechanization and other technological developments that contribute so much to increased agricultural productivity.

"In large part, this fact can be accounted for by the large resource gaps, including physical capital and entrepreneurial abilities, that must be bridged to employ effectively the new technologies. Left to their own limited resources and their present low levels of incomes, it is practically impossible for many of the nation's low income farmers to bridge these wide resource gaps, no matter how economically desirable the new technologies are."

Gardner (24, p. 768), in analyzing state differences in income inequality and their changes from 1949 to 1959, concludes:

"From the point of view of public policy concerning income inequality, the most significant aspect of this investigation may be the result that the factors normally associated with "progress" --technical change, increase in schooling and increased capital per farm-- appear to have increased rather than decreased the variance of equilibrium income."

All these studies except that of Kendrick appear to suggest the possibility that technological advance has the effect of increasing income inequality among farm families. As for Kendrick's study, his income equality increasing forces appear to function under the condition that the productive resources in the individual firms and families are quickly adjusted to changing technology. If we consider the whole economy over a long period, this would be true. However, in an industry in which serious resource immobility prevents needed adjustments, the other forces may dominate, thus increasing income inequality.

II. DEFINITIONS

A. Technological Change

1. Definition

Technological change is defined as qualitative changes in the way in which the production of goods and services is performed.¹

¹There is another definition of technological change, i.e., changes in the society's knowledge of the ways of production. According to this definition, any change in the knowledge is technological change whether it is actually used in the society's actual production. Apparently, this definition comes from the original meaning of the word technology. See:

"Technology: 1. the science or study of the practical or industrial arts. 2. the terms used in a science, are etc.; technical terminology. 3. applied science" (Webster, 67, p. 1496).

"Technology is the society's pool of knowledge regarding the industrial arts. It consists of knowledge used by industry regarding the principles of physical and social phenomena . . . , knowledge regarding the application of these principles to production . . . , and knowledge regarding the day-to-day operation of production Technological change is the advance of technology, such advance often taking the form of new methods of producing existing products, new designs which enable the production of products with important new characteristics, and new techniques of organization, marketing, and management.

"It is important to distinguish between a technological change and a change in technique. A technique is a utilized method of production. Thus, whereas a technological change is an advance in knowledge, a change in technique is an alteration of the character of equipment, products, and organization which are actually being used" (Mansfield, 47, pp. 10-11).

My understanding of technological change is rather that it is a process in which the new knowledge is actually used in the society's production. An invention which has been left unnoticed for (footnote continued on following page)

By qualitative change, we mean that there has to be something more than mere changes in quantities of inputs or outputs. It implies opportunities to use new inputs or produce new outputs, all of which have not been used by or known to particular firms considering the change or to society as a whole.

By stating that technological change involves changes in the way production is performed, we mean that it includes not only changes in the methods of production but also (1) the introduction of new products, (2) changes in the firm's managerial and financial structures, and (3) changes in marketing methods.¹ By the production of goods and services,

(footnote continued from previous page) decades by anyone but the inventor himself has not caused any change in the ways of production. It simply remains to be a potential change as compared with a realized change.

¹Schumpeter listed five categories of development (58, p. 66).

"Development in our sense is then defined by the carrying out of new combinations.

"This concept covers the following five cases: (1) The introduction of a new good--that is one with which consumers are not familiar--or of a new quality of a good. (2) The introduction of a new method of production, that is one not yet tested by experience in the branch of manufacture concerned, which need by no means be founded upon a discovery scientifically new, and can also exist in a new way of handling a commodity commercially. (3) The opening of a new market, that is a market into which the particular branch of manufacture of the country in question has not previously entered, whether or not this market has existed before. (4) The conquest of a new source of supply of raw materials or half-manufactured goods, again irrespective of whether this source already exists (footnote continued on following page)

we understand that it includes changes taking place not only in manufacturing and agricultural industries but also in transportation and other service industries.

This broad definition is directly applicable to the agricultural industry. It covers, however, too broad a category of changes to be examined in this study. Therefore, the term technological change is understood to have a narrower meaning than the above definition. In this study, it means the introduction of new inputs into agricultural production. The term is used in this way because we believe that changes in productive inputs have been the most important factor in causing rapid changes in the agricultural industry.

2. Innovation, adoption and diffusion

Each individual firm is unique, and each technological change it makes is unique, too. When we look at the industry as a whole, however, there is marked similarity among changes made by different firms over a given period of time. This is because all firms are under the pressure of heavy competition. Whenever a member of a particular industry makes a technological change which proves to be profitable, the rest of the industry has an incentive to take advantage of the same

(footnote continued from previous page) or whether it has first to be created. (5) The carrying out of the new organization of any industry, like the creation of a monopoly position (for example, through trustification) or breaking up of a monopoly position.

improvement. Thus, as an improvement emerges in a part of the industry, there are forces which tend to diffuse its use over the rest of the industry.

The term "diffusion" is given to this process in which an improvement made by a (group of) firm(s) is imitated by other members of the industry. This act of imitation by individual firms is called "adoption." On the other hand, its initiation into the industry, i.e., the introduction of an unknown technique is called an "innovation".¹ A firm which introduces the improvement first in the industry (or in a particular community) is an "innovator."

3. Meaning of technological change

The term "technological advance" is often used instead of technological change. It is used because technological change is supposed to have a certain feature desirable for its adopter or society as a whole. It is often stated that technological change makes it possible to produce more from a given amount of inputs. Our question is: What does this exactly mean?

A rather common understanding of technological change is to perceive it as a change in the production function. It is also changes in the production coefficients of factors.

Heady states that technological improvement is the "develop-

¹"An invention, when applied for the first time, is called an innovation" (Mansfield, 48, p. 99).

ment of a new production function such that a greater output of product is forthcoming from a given total input of resources (30, p. 802). Here, technological change is viewed as a change in the production function; the factors of production which have exactly the same quality before and after the change are the independent variables of the function.

There is another view of technological change. Schultz argues that "the notion of 'technological change' is in essence a consequence of either adding or dropping, or changing at least one factor of production." He points out "the apparent mistaken belief that a 'technological change' can be treated as if it were logically possible to separate a technique of production from the factors of which it is a part." Its consequence is that "economists have fallen into the practice of dividing the productive agents into two parts, one of which consists of 'land, labor, and capital (goods)' and the other of 'technological change'. But what is all too seldom recognized in making this division is that the term 'technological change' is merely a bit of shorthand for an array of (new) factors of production that have been omitted in the specification of the factors" (57, pp. 132-133).

According to this view, technological change involves the introduction of new factors of production. It is a

creation of a new production function because it has at least one factor which did not exist in the production function before the change.

Technological change usually involves factor substitution (or complementarity). Substitution may take place between factors which perform similar functions, for example between the seed of a conventional crop variety and that of an improved high yield variety. Or it may take place between factors which have quite different natures and functions, for example between an improved machine and labor.

This latter view appears more realistic in our study because not all inputs after technological change have the same quality as the ones before the change. The view that technological change is a change in the production function, on the other hand, is based on the assumption that all inputs are the same as the ones before the change. In reality, this assumption never holds true except in an approximate sense. It is based on the aggregation of inputs, using the common units of measuring scale, most typically the market values of the inputs.

What do we mean by "an increase in output from a given amount of inputs"? When we say that the output/input ratio has increased due to technological change, its denominator does not have exactly the same quality. It simply means that

output per dollar of the sum of different inputs valued at market prices has increased. Suppose its denominator remains constant, while its numerator increases. This total value of the denominator includes at least one component whose quantity has increased and one whose quantity has decreased.

4. Output increase and factor substitution due to technological change

It has been stated above that technological change always involves factor substitution. The above discussion also suggests that the output increasing effect of technological change has a meaning a little different from what it is usually understood to be, i.e., an increase in the output from a given amount of input. It is convenient to have these two terms--the output increasing (expansion) and factor substitution effect of technological change--clearly understood within the framework of our study, because they are used in later chapters.

a. Output increasing (output expansion) effect We say that output per unit of input has increased, when output per unit of aggregate value of inputs has increased, the aggregation of inputs being made by using their prices as weights.

b. Factor substitution effect The factor substitution effect of technological change is typically defined as a change in the relative productivities of labor and capital

inputs, i.e., a relative change in the marginal productivity of these inputs. Although we follow this definition, it has to be remembered that both capital and labor inputs are the aggregates of many components and that substitution is taking place also within each group.

5. Cost reduction

A reduction in per unit cost of production takes place as a result of substituting certain inputs for others. An illustration is given regarding how factor substitution leads to cost reduction. Factor substitution takes place between a new input (X_2) and an old input (X_1) because the ratio of the marginal physical product of X_2 to X_1 is greater than the price ratio of these inputs.

Suppose the production involves only X_1 or X_2 . The production isoquants are shown in Figures 2.1 and 2.2. Figure 2.1 shows ordinary isoquants on which the old input (X_1) is replaced by the new one (X_2) at a decreasing ratio. In Figure 2.2, X_1 is replaced by X_2 at a constant ratio. This may be the case when the quantities of nutrients in feed or fertilizer are the determining factors of the amount of production.

Two price situations are illustrated by P_A and P_B . P_B is steeper than P_A . Suppose in both cases input X_2 was not used in the farm before and it was in equilibrium at X_{10} level of input X_1 . Suppose input X_2 is introduced and the

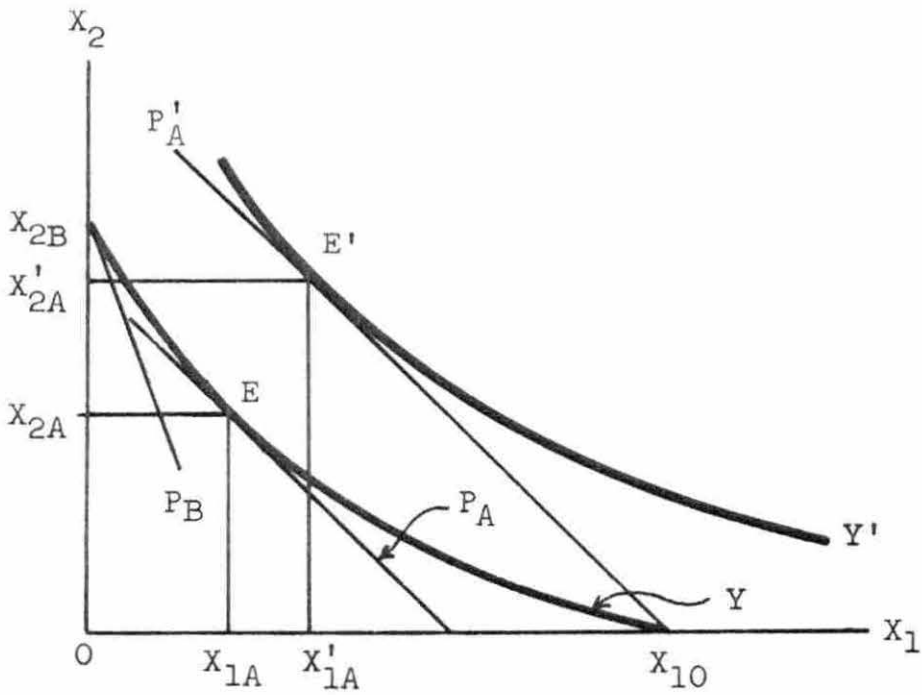


Figure 2.1. Cost reduction due to technological change with declining marginal rate of substitution

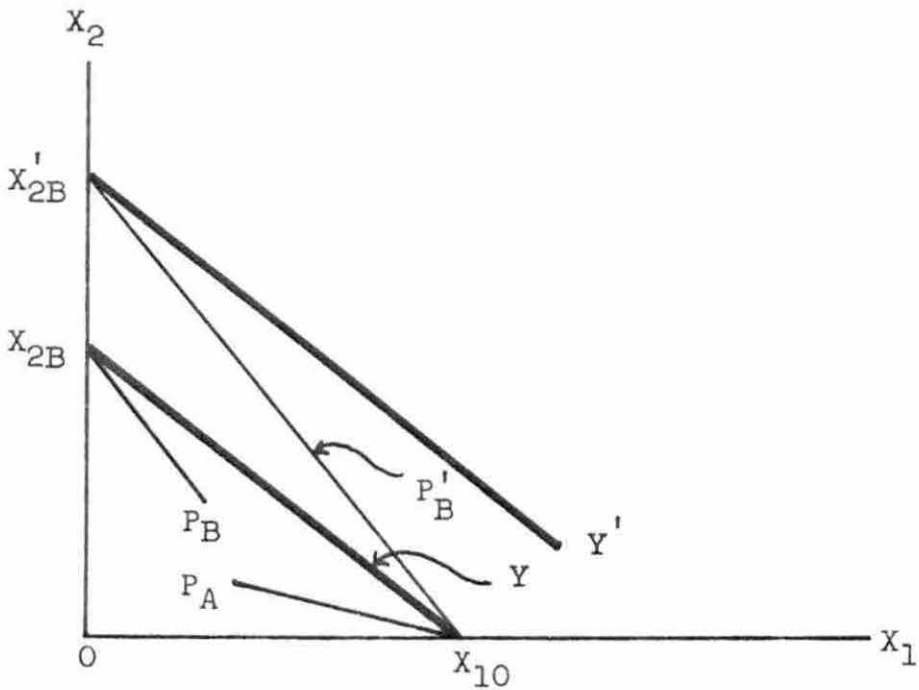


Figure 2.2. Cost reduction due to technological change with constant marginal rate of substitution

farm firm tries to optimize its inputs under price condition P_A , maintaining the same amount of output. Then, the firm will operate at E, using X_{1A} of input X_1 and X_{2A} of input X_2 . The total costs of production are now reduced from P'_A to P_A .¹ Since the same level of output is maintained, the average cost per output is reduced. If the firm tries to maintain its level of outlay at P'_A , then it will produce output Y' ($Y' > Y$). Input levels will be X'_{1A} and X'_{2A} , respectively. Again the average cost per unit of output declines. Under price condition P_B , the farm will shift its input completely to X_2 . The input level to maintain the old output will be X_{2B} . The average cost declines in this case, too.

If the rate of factor substitution is constant over the entire range, only one of two inputs will be used as shown in Figure 2.2. When the price condition is P_A , no input change will take place. In other words, the change is not adopted. On the other hand, if the prices are as P_B instead, only X_2 will be employed. Its level will be X_{2B} in order to maintain the same amount of output and X'_{2B} in order to maintain the same outlay. In the second case, output increases from Y to Y' . In either case the average cost declines as a result of the adoption.

¹The total outlay or costs is measured by the distance between the cost line and the origin.

B. Income and Income Distribution

1. Family income and wealth

In our study, the concept of income is applied on a personal or family basis. Ignoring all possible complications arising from (1) possible changes in interest rates, (2) possible changes in prices, and (3) inaccurate expectations of the future earnings, income is defined as follows:

"Income is . . . the maximum amount which can be spent during a period if there is to be an expectation of maintaining intact the capital value of prospective receipts in money terms" (Hicks, 37, p. 173). In general, the level of family income is dependent on (1) quantity and quality of resource owned and offered, directly or indirectly, in income generating employments, (2) the rates of factor earnings on these resources, and (3) the tax and transfer policies of government.

Let us assume that the net effect of tax and transfer payments on the level of income is zero, i.e., the family pays taxes as much as it receives from government. Let us ignore the value of all durable consumer goods the family owns (including its house). Let us also assume that the family derives its income only from its farm, that its investments are made only in the farm firm and that all resources in the farm firm are owned by the family. In this case, family wealth can be defined in relation to the income produced in the farm. The family's wealth is the capital value

of its prospective receipts, i.e., the present value of the farm's (the family's) future earnings.

2. Farm size

Farm size is viewed as a firm's income generating capacity. In this sense, it is most adequately measured by firm value, i.e., the present value of the firm's expected future earnings. The amount of land or the total value of investment in land and physical capital are also used as a measure of farm size because these are related to the firm's earning power. A flow concept is often used instead of the stock concept explained above. Firm size is measured by the total sum of the opportunity cost of services provided by the factors of production in the farm. It is also measured by the total amount of output. Again, this scale is used primarily because it has a close relation to the farm's annual earnings, although "the level of output" may have its own significance in relation to economies of size, etc.

In this study farm size is defined as the farm firm's income earning capacity. Thus defined, there is one-to-one relationship between the farm's income and its size, except that a part of total income generated (net value added) by the farm goes to lenders and landlords. It follows that a family which operates a large farm obtains a high income and one which operates a small farm gets a small income. Therefore, the words large and small farms will be used inter-

changeably with high and low income families, respectively.

Discrepancy between farm size measured by our scale and one measured by the conventional scales such as output size, acreage, asset values, etc. arises from the following causes: (1) An essentially different thing is measured instead of the farm's income--e.g., the amount of output. (2) Failure to take into account all factors of production--e.g., management (and labor) is in most cases left out of input measurement. (3) Failure of the market value of an input factor to coincide with its marginal value productivity--the farm is in disequilibrium either due to a short-run disturbance because of technological change or due to capital rationing.

3. Income distribution and inequality

Interest has been focused on three types of income distribution (Bowman, 7):

- (1) Industrial distribution of national income
- (2) Functional distribution
- (3) Personal distribution

We are concerned with the distribution of type (3), i.e., personal size distribution of income. Income inequality, i.e., the degree to which income is distributed unevenly among families has received a great amount of attention. What is the optimal or reasonable (socially tolerable, sometimes) income inequality among families in the society? The question has never been answered satisfactorily. This is so

(1) because the question involves a value judgement and (2) because of difficulty of establishing the most appropriate measure or criteria of income inequality. However, there seems to be considerable social agreement that increasing income inequality is not desirable in our present situation.

A great number of attempts have been made to measure income inequality. Bowman (7) summarizes these measures. Among them are:

- (1) Pareto coefficient
- (2) Gini curve
- (3) Lorenz curve and Gini concentration ratio

Two criteria are frequently used in order to judge whether income inequality has increased or decreased. One is stated in relative terms and the other, in absolute terms.

According to the first criterion, income inequality increases when the income of the rich increases by a greater percentage than that of the poor. Those three measures summarized by Bowman follow this criterion of relative inequality. Gini ratio is most widely used among them. According to the second measure, inequality increases when the income of the rich increases by a greater absolute amount than that of the poor. It is quite possible that the absolute difference in income increases even if relative inequality remains constant or decreases.

The absolute measure is used in this study. It is not

easily stated which of these two criteria of measuring income inequality is more relevant to society's concern. The inequality measure of absolute terms is chosen for the sake of analytical simplicity rather than from the consideration of its implication for social welfare. Whichever measure we may choose, it is difficult to numerically specify income inequality without empirical data. However, the absolute inequality appears to be easier to measure because the relative measure involves more rigorous specification of such variables as cost-revenue ratios, resource ownership, etc. Therefore, unless it is specially stated that the income distribution is described in relative terms, our analysis is made in absolute terms.

C. Saving and Investment

1. Saving and investment

Saving is defined as the difference between the family's actual consumption and its income defined above. If the family consumes less than its income, it saves. If it consumes more than its income, it dissaves. This saving is either held in the form of money, invested in additional income opportunities outside its farm, or invested in the farm.

The significance of saving lies in (1) meeting future contingencies and (2) increasing future income through investment. We are interested in saving because difference

in saving and investment behavior changes (1) the farm's income earning capacity and (2) the rate of factor earning due to the cost economies associated with farm size.

Investment in the farm is defined as a net addition to the farm's capital value. It is an addition to the farm's capacity to generate income.

Investment in the farm takes the form of either increasing physical capital or improving human resources. We encounter a difficult problem, i.e., whether education is consumption or investment. From a private farm firm's point of view, education and training of human resources utilized in the farm is included in investment. If the farmer-operator's planning horizon does not go beyond his own generation, his children's education is not considered to be investment in his farm.

The sources of investment are (1) the family's own saving and (2) its borrowing. As analyzed later, the farm's saving, borrowing and investment have important implications on farm firm growth and income distribution.

2. Investment in technological change

As clarified in chapter IV, the farm firm's investment is closely associated with technical improvements the farm makes. Although improvements without additional investment are possible within the farm, the nature of technological change tends to induce a greater amount of investment compared

with the situation in which no technological change takes place.

Investment induced by (made in order to take advantage of) a specific (series of) technical change(s) is called "investment in technological change". This is divided into two categories, i.e., "investment in information" and "investment in adoption". The first category includes all resources required for the operator's decision on the adoption of the improvement. It includes the operator's time and money spent (1) on his information search activities such as attending extension meetings, consultations with agents or local bankers, reading publications, and (2) making his own assessments and decisions on its adoption. The second category is the investment made in order to make the improvement itself, i.e., investment in physical and human resources necessitated by the improvement.

In reality the distinction is not clear. The two are closely interrelated. For example, market outlook and weather forecasts for the season may be used in making adoption decisions. They also may be used in making decisions which do not involve technical improvements. Investment in physical resources and their uses will give the farmer the working knowledge of potential improvements he might consider in the future. These examples show that in many occasions these two types of investment activities proceed in parallel.

To some extent, they are complementary with respect to resource use, although they may compete with each other beyond a certain range. The purpose of this distinction is to use it in the analysis of the farmer's decision making process related to the adoption of technical improvements.

D. Main Hypothesis Restated

Since major concepts used in this study have been defined, the clarification of our main hypothesis in the light of these definitions is now in order. Here we briefly examine our main hypothesis in relation to the concepts of technological change and income.

1. Technological change

As already mentioned, only a narrow range of technological changes, i.e., changes which are directly related to the farm firm's production process are considered. Our special interest is focused on the introduction of new inputs in production because it is believed to be the major part of technological change which has produced the greatest impact on output, prices, income, and resource employment.

2. Farm income

The farm family's income consists of (1) income from farming, (2) income from nonfarm sources, and (3) transfer payments. All kinds of government's farm program payments

are included in category (3), although it is difficult, in reality, to separate program effects on output and prices in such cases as the price support programs.

The main effect of technological change falls on income from farming. A part of transfer payments may be affected because the present program payments are closely tied to farm size measured by the farm's output or acreage. Nonfarm income might be affected, too, but only indirectly through resource movements into and out of the farm.

We can look at our hypothesis in the following way: The impact of technological change falls directly on the income of farm origin in such a way that its inequality among farms increases. On the other hand, resource adjustment between farm and nonfarm sectors typified by labor movement out of agriculture offsets a part of this effect of income inequality increase. The trend in income inequality, in effect, is determined by the balance between these two factors.

Our attention is focused on the first process, namely, the effect of technological change on the income of farm origin under the assumption that farm-nonfarm resource adjustment is restricted. The process of resource adjustment between farm and nonfarm sectors in response to inequality effects as well as in response to other consequence of technological change is analyzed briefly toward the end of this study.

Finally, our hypothesis goes one step further and says that, on balance, income inequality among farms increases as a result of technological change. This is because of the process whereby resource adjustment lags behind the disequilibrium created by technological change.

E. Two Farms--A Stereotype

Two typical farms A and B are on stage throughout this study. Farm A has higher income and a greater size of operation than farm B. Farms A and B are assumed to have the general characteristics of the large and the small family farms in contemporary U.S. agriculture. On the large farm, operator income is large. The family's propensity to save is high. The operator has great managerial ability and is more willing to run a risk. Farm B's characteristics are assumed to be exactly opposite to those of farm A. The family's saving propensity is low. The entrepreneur has inferior managerial ability and is less willing to bear a risk. These characteristics are described in detail in chapter III.

These two typical farms are allowed to react to a series of technological changes according to their characteristics. In other words, their behavior is analyzed in the light of their characteristics. Behavioral differences together with the effect of technological change on the farms' costs and revenues, will tell us whether income differences have widened

or narrowed.

In a strict sense, income inequality cannot be described completely by differences between two typical components of society. For example, such differences cannot distinguish between two situations; one with a large group of poor to middle income families within which no great inequality exists, and a small group of extremely rich people; the other with a small group of extremely low income people and a large group of middle to upper income people. Yet, our analysis of differences between two farms will give us sufficient information through which we can determine whether income inequality widens or narrows as a result of technological change.

Our farms are supposed to be in relatively high and low income groups but not so far away from the middle as to deviate from the range of commercial family farms. They are also assumed to be in the same stage of the family cycle--a period in time considerably before retirement.

III. MAJOR ATTRIBUTES OF THE FARM FAMILY AND FARM FIRM

This chapter is devoted to the discussion of background knowledge needed for our analyses of the effects of technological change. First, the nature of the family farm is outlined, particular attention being given to resource availability to the family farm. Second, the size of the farm firm and its relation to input composition and cost economies are described. Third, the family's saving and investment behavior is analyzed. Fourth, the operator's willingness to bear risks is discussed. Finally, since the farm operator's decision making plays an important role in the adoption of technical improvements, differences in the operator's managerial ability and efficiency in entrepreneurial information search activities are examined. The result of these discussions are applied to our later analysis of the effect of technological change on income distribution, in which the farms adoption behavior, changes in the price of output and farm firm growth play important roles.

A. Family Farm

1. Family farm

The family farm is "defined as a farm where most of the labor and management are combined in the same individual or family" (Smith, 61, p. 13).

It has been generally recognized that the family farm

has been dominant in the U.S. agriculture. Why has it been so? It may be the result of lack of technology which places the larger-than-family farm in a more favorable position than the family farm. Or it may be a historical product of the period of earlier settlement combined with high social value placed on the family farm (Soth, 64, p. 22). It is not our objective, however, to study the environment which has made the family farm the most common form of agricultural production. Our objective is rather to examine the consequences of the fact that the family farm has established a pattern of resource supply to its production.

Suppose farms are under heavy pressure to expand input size and change production processes due to rapid change in technology. Our questions are: Is the family farm flexible enough to respond to this change? Is it possible, within the framework of the family farm, to increase input size quickly and efficiently in order to reap the full gain from large scale operation made possible by new technology?

2. Family farm and resource restriction

As suggested above, a set of restrictions is imposed on the availability of new inputs because of the fact that the farm is operating within the framework of the family farm. All input factors--land, labor, capital, and management--are restricted in some way or other.

This restriction appears to arise from close interrelation between farm family as a consumption unit and the farm firm as a production unit. A large part of input factors utilized in farming are supplied by the family and their availability is always limited by the family's supply capacity.

These productive factors do not have to be owned by the family. Capital could be borrowed; land could be leased; labor could be hired; and management could be supplemented by outside services; just as they are in the industrial firm. But none of these factors seems to have increased far beyond the family's supply capacity. Although detailed examination of these limiting factors is not made here, there is a strong indication of restriction on the acquisition of these factors. These restrictions are discussed in section C.

3. Objectives of the farm family and the farm firm

The objective function of the family farm is a unique combination of those of a consumption unit and of a production unit (Heady, 30, pp. 416-435; Bivens, 4, esp. pp. 1-12). The objective of the farm family is to attain maximum family welfare which includes both income and nonincome aspects. The nonincome aspect of its welfare includes such factors as being your own boss, living in the open country (Kaldor, et al., 40), amount of leisure, etc. The family's preference between income and nonincome factors appear to become more

in favor of the latter as income increases. On the other hand, the objective of the firm in general is to maximize its capital return or entrepreneurial rewards. The firm's objective function is more growth oriented because it attempts to exploit profit opportunities to a maximum extent.¹ But in the family farm, family objectives are imposed on this objective. This could modify the firm's objective to a great extent. In other words, the emphasis the farm firm places on the pursuit of profit may be considerably less than that of the industrial firm where firm objectives are independent of family objectives.

B. Farm Firm and Its Size

1. Farm size

Statistics show that there exist wide differences in input and output sizes among farms. Since no readily available data show the distribution of farm size that follows our definition, the distributions of sales, farm value, and acreage taken from the 1965 Census of Agriculture are shown in Tables 3.1, 3.2, and 3.3. These tables show that farm size differs widely according to any criteria used in the tables.

¹Penrose goes one step further and says that the firm's objective is to increase "total long-run profit" through expansion: "Growth and profit become equivalent as the criteria for the selection of investment programmes To increase total long-run profit of the enterprise in the sense discussed here is therefore equivalent to increase the long-run rate of growth" (51, p. 30).

Table 3.1. Farms by economic class, United States, 1964^a

Class ^b	Farms (1,000)	Percent
Total all farms	3,158	100.0
Commercial farms		
Total	2,166	68.6
Class I (\$40,000 or more ^c)	142	4.5
Class II (\$20,000 to 39,999)	260	8.2
Class III (\$10,000 to 19,999)	467	14.8
Class IV (\$ 5,000 to 9,999)	505	16.0
Class V (\$ 2,500 to 4,999)	444	14.1
Class VI (\$ 50 to 2,499)	348	11.0
Other farms		
Part time	639	20.2
Part retirement	351	11.1
Abnormal	2	.1

^aSource: (66, p. 638).

^bEconomic class, definition by the Census of Agriculture.

^cTotal value of all product sold.

A part of the differences could be explained by (1) differences in economic, climatic and other conditions associated with location and (2) different types of production in which the farms participate. But the same Census data, although they are not shown here, seem to indicate considerable differences even after these geographical and farming type differences are eliminated.

Table 3.2. Commercial farms by value, United States, 1964^a

Farm value	Farms (1,000)	Percent
Less than \$10,000	334	15.4
\$10,000 to 19,999	343	15.9
\$20,000 to 39,999	520	24.1
\$40,000 to 69,999	427	19.7
\$70,000 to 99,999	202	9.3
\$100,000 to 149,999	153	7.1
\$150,000 to 199,999	69	3.2
\$200,000 to 499,999	88	4.1
\$500,000 or more	23	1.2

^aSource: (66, p. 638).

Table 3.3. Commercial farms by size in acres, United States, 1964^a

Size ^b	Farms (1,000)	Percent
Less than 10 acres	84	3.9
10 to 49 acres	272	12.6
50 to 69 acres	104	4.8
70 to 99 acres	192	8.9
100 to 139 acres	222	10.3
140 to 179 acres	241	11.1
180 to 219 acres	159	7.3
220 to 259 acres	143	6.6
260 to 499 acres	410	18.9
500 to 699 acres	115	5.3
700 to 999 acres	83	3.8
1,000 to 1,999 acres	82	3.8
2,000 acres or more	58	2.7

^aSource: (66, p. 638).

^bTotal land area.

2. Input composition and farm size

There is a substantial difference in input composition between large farms and small farms. Tables 3.4 and 3.5 show input differences among farms with different farm sizes (measured by acreage). Data from both Iowa and Illinois Farm Business Records indicate that variations in land and capital are greater than that of labor. They also show that the amount of capital per man year of labor is greater for large farms than small farms.

3. Cost economies of large farm size

There has been an unsettled controversy over the question of whether there exist scale economies in agriculture (Heady, 30, pp. 350-360). However, there seems to exist a sufficient amount of evidence to show cost economies associated with large size of operation. These cost economies are largely a product of different input composition accompanying farm size difference. Heady states (31, p. 136):

"On-the-farm scale returns or cost economies arise mainly from mechanical innovations such as those relating to power, machinery, equipment, and buildings. They are only slightly, or not at all, related to such biological innovations as new seed varieties, fertilizer, insecticides, and chemicals. Power units, field machines and harvesters of greater capacity, and larger crop-handling equipment have particularly increased the size or average range over which declining per unit costs prevail in cotton, corn, wheat, and other field crops. Also, the greater capacity and productivity of these machines has substantially increased the number of acres, animals, and birds which can be handled by one man or the farm family. Since the fixed costs of these high capacity

Table 3.4. Farm resources used by size of farm in acres, northern Iowa, 1967^a

	Average	70-179 acres
Acres per farm	261(100) ^b	153(59)
Capital (\$100):		
Feed and livestock	428(100)	241(56)
Machinery and equipment	113(100)	71(63)
Land and improvements	1,046(100)	650(62)
Total	1,587(100)	962(61)
Labor-Months:		
Operator	12.1(100)	11.3(94)
Family	1.2(100)	1.4(117)
Hired	2.4(100)	.3(13)
Total	15.7(100)	13.0(83)
Capital per 12 months of labor (\$100)	1,213(100)	888(73)

^aSource: (17, p. 4).

^bNumbers in parentheses are the percentage ratios of each item to the average values.

180-259 acres	260-359 acres	360-499 acres	500 acres and over
227(87)	310(119)	425(163)	671(257)
419(98)	480(112)	664(155)	1,082(253)
114(101)	125(111)	171(152)	230(204)
939(90)	1,223(117)	1,684(161)	2,365(226)
1,472(93)	1,828(115)	2,519(158)	3,678(232)
12.0(99)	13.0(107)	12.3(102)	13.6(112)
1.2(100)	1.0(83)	.6(50)	.9(75)
1.8(75)	3.0(125)	7.1(296)	10.5(438)
15.0(96)	17.0(108)	20.0(127)	25.0(159)
1,178(97)	1,290(106)	1,511(125)	1,765(145)

Table 3.5. Farm resources used by size of farm in acres, northern Illinois, 1961 (grain farms with soil rating 76-100)^a

	Under 180 acres
Number of farms	34
Total months of labor	12.0(79) ^b
Farm investment (\$)	
Livestock inventory	2,718(61)
Grain inventory	7,730(61)
Remaining capital cost in:	
Machinery	3,256(52)
Buildings and fence	10,380(79)
Soil fertility	337(91)
Auto	454(57)
Value of land (current basis)	<u>65,817(51)</u>
Total farm investment	90,692(54)
Total farm investment per acre	600.61(109)
Total farm investment per 12 months of labor	90,692(69)

^aSource: (1, p. 11).

^bNumbers in parentheses are the percentage ratios of each item to its average value of 260-339 acre farms.

180-259 acres	260-339 acres	340-499 acres	500 acres and over
80	104	132	110
13.2(87)	15.2(100)	19.0(125)	28.4(187)
3,655(82)	4,451(100)	5,669(127)	10,279(230)
10,020(79)	12,694(100)	17,191(135)	26,460(208)
5,499(87)	6,290(100)	8,450(134)	12,629(201)
9,540(72)	13,156(100)	15,822(120)	23,848(181)
419(113)	368(100)	426(116)	842(229)
663(84)	790(100)	785(99)	841(106)
<u>97,393(75)</u>	<u>129,877(100)</u>	<u>172,813(133)</u>	<u>271,302(209)</u>
127,189(76)	167,626(100)	221,157(132)	346,201(207)
567.81(103)	553.22(100)	548.78(99)	529.36(96)
115,626(87)	132,336(100)	139,678(105)	146,282(111)

machines are greater than those of machines used prior to World War II, the curve of per unit costs declines more sharply over larger outputs. A greater gain in net returns per unit is thus realized as size increases."

A series of empirical evidences shows that the cost curve slopes downward to the right within the range relevant to our study (Heady, McKee and Haver, 35; Barker and Heady, 2; Heady and Krenz, 34; Ihnen and Heady, 38; Brewster and Wunderlich, 9). Data obtained from the farm business records also support the above arguments. Tables 3.6 and 3.7 show that total cost per acre declines as the farms' acreage size increases. Labor and machine (including building and equipment) costs decline individually, too. But the percentage decrease in labor cost is greater than percentage decrease in machine and other capital costs. Since labor has a large share in total costs, it is the greatest contributor to the cost economies of large scale operation.

C. Saving, Investment and Their Relation to Income Level

Saving and investment behavior differs between high income and low income families. This difference in investment behavior affects the farm firm's adoption decisions and its growth process induced by technological change.

1. Why does the family save?

There are two major reasons why the family saves out of its current income.

Table 3.6. Expenses per acre by size of farm in acres,
Iowa, 1967^a

Farm size groupings	160 acres
Machine and power cost	\$ 30.84(132) ^b
Taxes, insurance and building depreciation	16.64(130)
Crop expenses	15.47(103)
Labor hired	2.13(87)
Other expenses	<u>6.07(159)</u>
Total expenses ^c	71.15(124)
Operator and family labor	<u>31.06(184)</u>
Total, including operator and family labor	102.21(138)
Machine and power investment per rotated acre	57.47(109)

^aSource: (14, p. 7).

^bNumbers in parentheses are the percentage ratios of each item to its average value of 320 acre farms.

^cExcludes interest payments.

240 acres	320 acres	440 acres	600 acres
\$ 25.79(111)	\$ 23.33(100)	\$ 21.15(91)	\$ 18.52(79)
13.66(106)	12.84(100)	12.20(95)	10.91(85)
15.08(101)	14.96(100)	15.48(103)	16.00(107)
2.31(94)	2.46(100)	3.76(153)	5.16(210)
<u>4.48(118)</u>	<u>3.81(100)</u>	<u>3.12(82)</u>	<u>2.66(70)</u>
61.32(107)	57.40(100)	55.71(97)	53.25(93)
<u>22.09(131)</u>	<u>16.88(100)</u>	<u>12.87(76)</u>	<u>8.34(49)</u>
83.41(112)	74.28(100)	68.58(92)	61.59(83)
55.01(105)	52.54(100)	48.41(100)	46.07(88)

Table 3.7. Costs and returns per tillable acre by size of farm in acres, northern Illinois, 1961 (grain farms with soil rating 76-100)^a

	Under 180 acres
Number of farms	34
Soil fertility	\$ 8.07(122) ^b
Buildings and fence	6.71(149)
Machinery and equipment	22.97(123)
Labor	18.60(161)
Feed and grain returns	81.19(102)
Total value of farm production	90.63(102)
Total nonfeed costs	<u>96.72(124)</u>
Management returns	- 6.09(-56)

^aSource: (1, p. 11).

^bNumbers in parentheses are the percentage ratios of each item to its average value of 260-339 acre farms.

180-259 acres	260-339 acres	340-499 acres	500 acres and over
80	104	132	110
\$ 6.45(97)	\$ 6.64(100)	\$ 6.91(104)	\$ 7.16(108)
5.18(115)	4.49(100)	4.48(100)	4.21(94)
20.55(110)	18.64(100)	18.85(101)	17.18(92)
13.62(118)	11.52(100)	11.32(98)	11.08(96)
80.16(100)	79.94(100)	82.30(104)	82.34(104)
91.62(103)	88.69(100)	91.76(103)	89.40(101)
<u>83.39(107)</u>	<u>77.76(100)</u>	<u>77.58(100)</u>	<u>75.12(97)</u>
8.23(75)	10.93(100)	14.18(130)	14.28(131)

1. The family may desire to have a greater amount of income in the future than it does at present. Future income can usually be increased only by investing current income in additional income generating activities.
2. The expected future income has a certain degree of uncertainty attached to it. As discussed in section D, certainty is preferred to uncertainty. One important way to reduce uncertainty over future income is to set aside a part of current income and hold it in the form of either currency or additional income generating activities through investment.

2. The family's preference between present and future consumption

In general, high income families save a larger percentage of their disposable incomes than low income families do. Why do they do so? Let us consider a family with considerably lower income than that which allows a "decent" level of living. The former has to decide how much to save and how much to spend for present consumption out of this small amount of income. The disutility due to failure to attain this minimum level of living at the present moment may exceed the disutility due to the expected reduction of future income caused by not saving at present. On the other hand, a family with income substantially higher than this level may be con-

cerned to a greater extent with the possibility of both increasing and stabilizing the expected future income.

Thus, we can draw a hypothetical indifference map of the family (Bivens, 4, pp. 33-35) as shown in Figure 3.1. This indifference map shows choice between present (C_p) and future (C_f) consumptions. Indifference curves U_1 , U_2 , and U_3 show successively higher levels of family satisfaction. Curve U_1 has a steeper slope than U_2 and U_3 , indicating that the amount of increase in the expected future income needed to compensate for the disutility of foregoing a given amount of present income is greater at a lower level of income than at a high level of income.

3. The family's decision on saving

The proposition that the high income family saves a larger percentage of its current income than the low income family can be graphically analyzed. Suppose high income farm A and low income farm B have current incomes W_A and W_B , respectively. Suppose that the only way for them to invest their incomes is depositing them at the interest rate i . Now, we can draw possibility curves K_A and K_B which indicate their possible choices between present and future consumption, which is done in Figure 3.2. They are straight lines starting from points W_A and W_B on C_p axis and have equal slopes $-(1 + i)$. Under the assumption that families A and B have identical preference functions, we can find their equilibrium

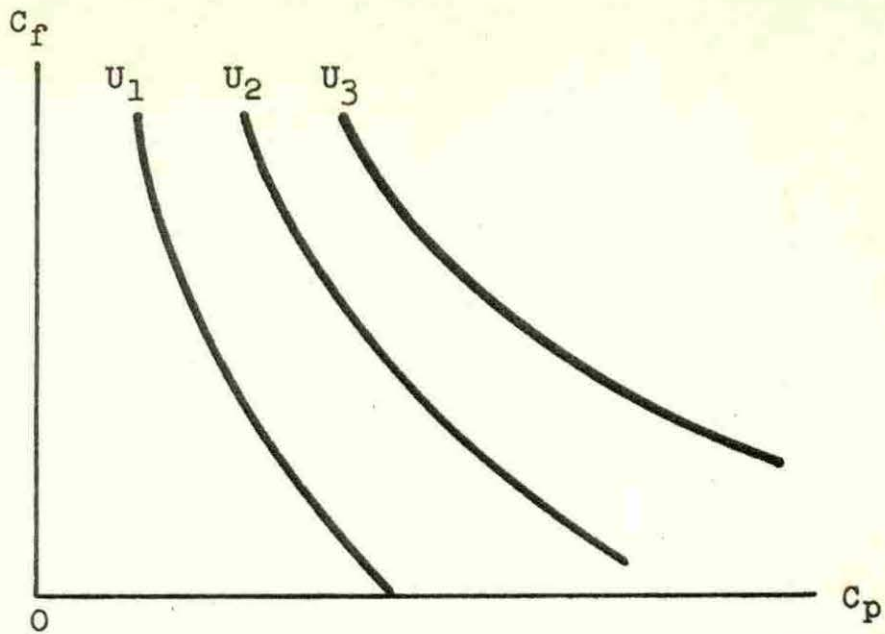


Figure 3.1. Family's indifference map showing choice between present and future consumption

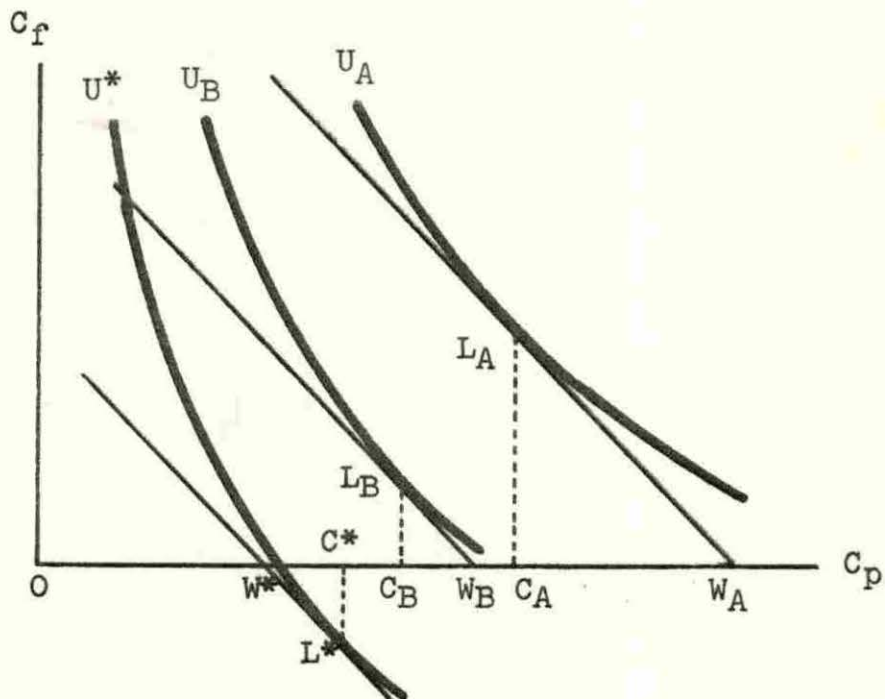


Figure 3.2. Family income and savings behavior

points at L_A and L_B , where their possibility curves are tangent to indifference curves U_A and U_B , respectively. The graph shows that farm A saves a greater relative as well as absolute amount than farm B. If the family income is extremely low, the family spends more than it receives as income, i.e., it dissaves. This situation is shown as point L^* in Figure 3.2.

4. The farm firm's investment decision

The farm firm's investment decision depends on three factors, i.e., (1) preference between present and future consumption, (2) the investment return, and (3) uncertainty associated with the investment. The second and third factors will be analyzed later in chapter IV and section D of this chapter, respectively. What is done in this subsection is to make an assumption on the firm's investment return and combine it with the first factor, the family's preference between present and future income. We want to show (1) that the high income farm family tends to invest more than the low income farm family when the investments yield equal returns on both farms and (2) that the high income family's tendency to invest a greater amount is intensified by the possibility that the large farm has a greater capacity to absorb investment profitably than the small farm does.

Suppose farms A and B have identical present and future consumption preference maps. Farm A has a greater amount of

income (W_A) than farm B does (W_B). Suppose the firms face a new investment opportunity. Suppose further that the investment returns of both farms are shown in the form of production functions. Their inputs are their new investments, outputs being the income increase due to the investments.

We can imagine two cases with respect to returns to the investments of these two farms, as shown in Figure 3.3. The first case, identified by subscript 1, is that both farms have identical return curves. In other words, both farms obtain the same size of return from the same size of investment. The second case, with subscript 2, is that farm A has a greater capacity to absorb investment profitably than farm B. That is, A's return curve extends farther to the right than that of B's. The first case might apply to the situation of expanding the total size of the farm along the expansion path. The second case can be understood as an expansion of a particular input, other input factors being fixed.

From these production functions in Figure 3.3, we can construct the consumption possibility curves between present (C_p) and future (C_f) consumptions. They are shown in Figure 3.4, together with the consumer's indifference map.

This indifference map analysis shows that in both cases farm A invests a greater amount. If the two have identical production functions, A's investment ($W_A - D_{A1}$) is greater

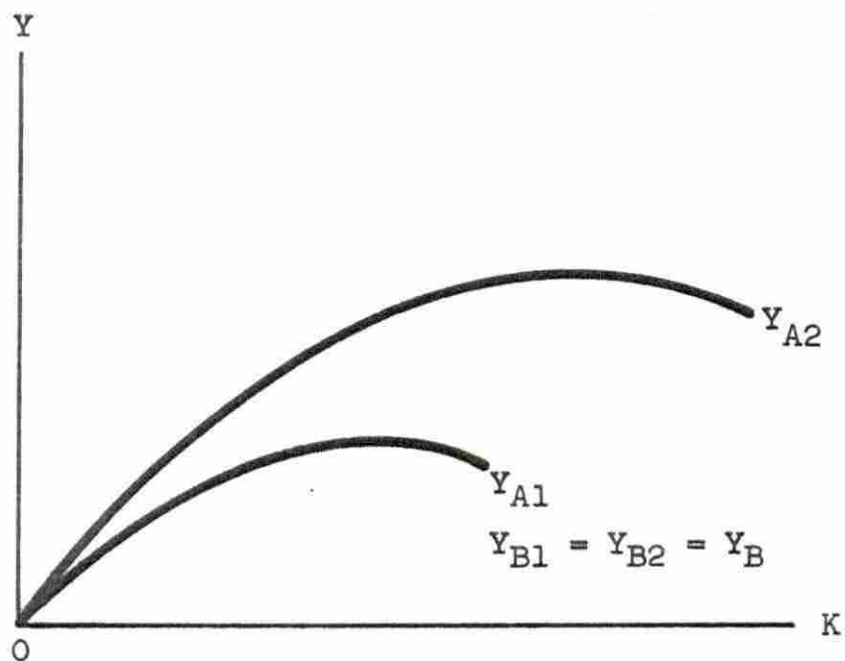


Figure 3.3. Returns to investment on large and small farm firms

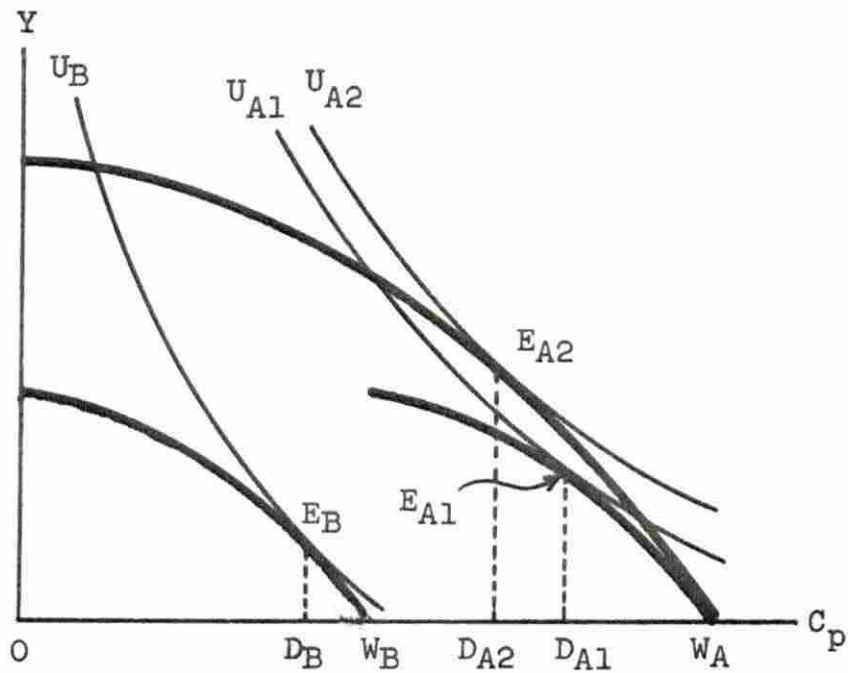


Figure 3.4. Large and small farms' investment behavior

than B's investment ($W_B - D_B$). If farm A has a greater capacity to absorb investment, A's investment ($W_A - D_{A2}$) is even greater than the first case, while B's investment is the same as the first case.

D. Family's Risk Aversion

1. Family's risk aversion

The family farm's risk aversion is based primarily on its desire for stable income. Such factors as the farm firm's survival or uninterrupted growth, and "the utility of gambling" are undoubtedly important in the farm's decision making. But the family's ultimate objective with respect to its income aspect is to realize stable income over an extended period (Heady, 30, pp. 504-505). In general, the family prefers less uncertainty to greater uncertainty regarding its income.

Our hypothesis is that, if two families are given chances from which they obtain equal expected payoffs with equal degrees of uncertainty, the high income family is more willing to take the risk than the low income family. This hypothesis is usually justified by saying that, if they should fail in the bet, it is more damaging to the low income family. As discussed in subsection 2, this hypothesis is based on another hypothesis of the decreasing marginal utility of income.

The individual's uncertainty is subjective and the measurement of this subjective uncertainty, particularly by

means of probability distribution, has theoretical difficulty (Hart, 27; Schackle, 56). However, since the simplicity of analysis is desired in later chapters, uncertainty is approximated by the probability distribution of the expected payoff in this study. It is assumed that certain parameters of the distribution function are known (subjectively) to individuals.

Under this assumption, uncertainty is typically measured by (1) the probability of sustaining net loss, (2) the expected value of net loss, or (3) the dispersion of payoff about its expected value. Although the first and second measure may be relevant to the farm's investment decision, they give only a part of the information regarding the degree of uncertainty. Therefore, the third, i.e., dispersion of the expected payoff is used as a measure of uncertainty.

The individual's risk aversion can be shown in the form of a risk-payoff indifference map as shown in Figure 3.5. Y denotes the expected value of payoff, R being the degree of uncertainty. A family of indifference curves shows successively higher level of satisfaction (U_1 , U_2 , and U_3). It shows that he attains higher level of satisfaction either (1) when R , risk is fixed and Y , the expected value of payoff is greater, (2) when Y is fixed and R is less, or (3) when R is less and Y is greater at the same time. Curve U_2

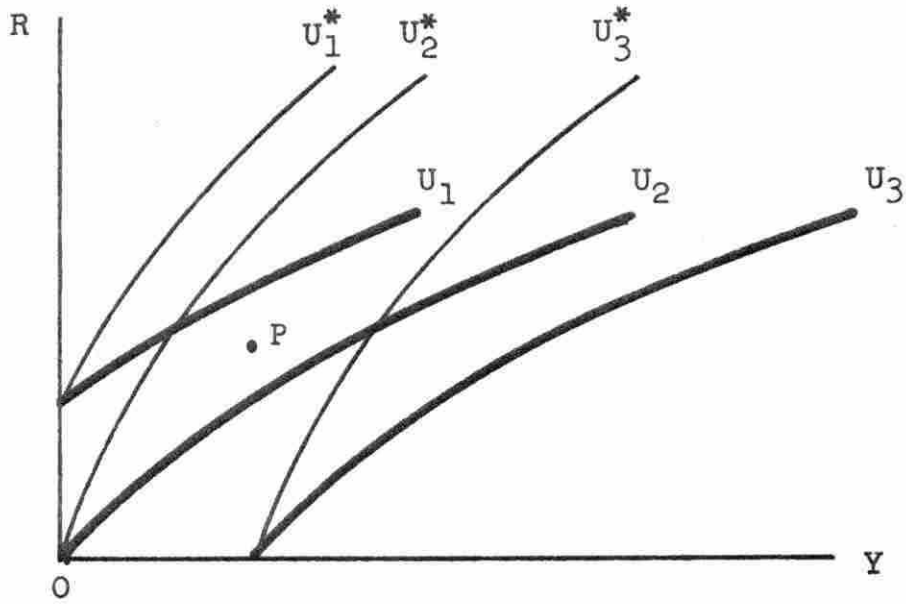


Figure 3.5. Family indifference maps for large and small farms, showing choice between expected pay-offs and uncertainty

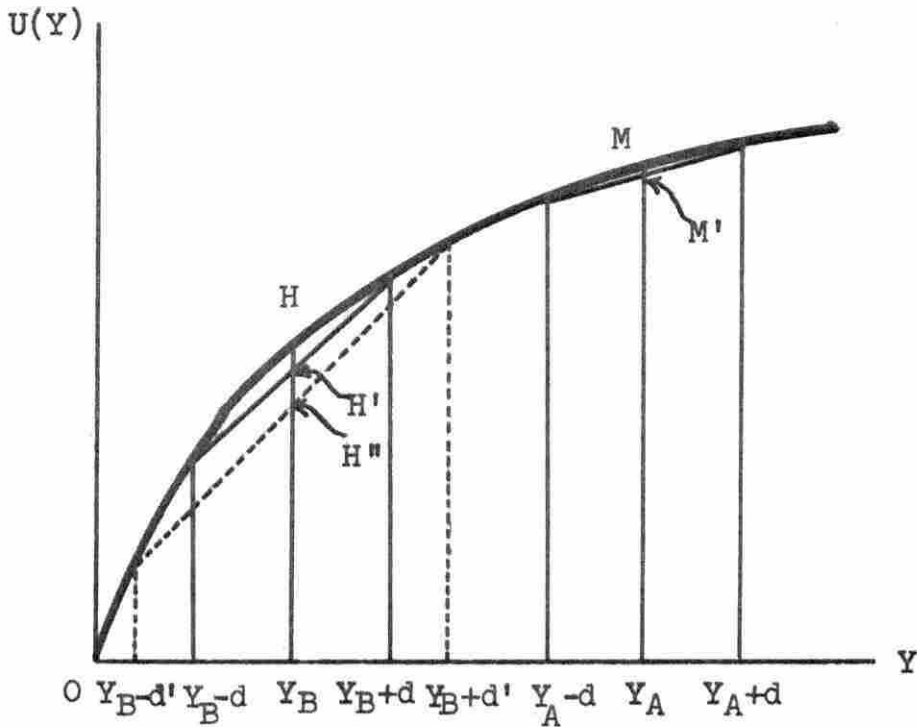


Figure 3.6. Relation of risk aversion to farm family income differences

shows the combination of risk and payoff which has an equal level of satisfaction to the situation of zero payoff and no risk, which is equivalent to avoiding the bet. He will refuse to make a bet (investment decision is one of this kind) when he is given any combinations located in the left-hand side of curve U_2 .

Another set of curves U_1^* , U_2^* , and U_3^* show the behavior of another person who is more willing to take a risk. His indifference curves are steeper than those of the first person. Notice that the latter is willing to make a bet when given the situation with combination P, while the former refuses to do so. We can say that curves U_1^* , U_2^* , and U_3^* characterize farm A (the high income family) and curves U_1 , U_2 , and U_3 characterize farm B (the low income family).

2. Decreasing marginal utility of income and risk aversion

This subsection is devoted to the derivation of two hypotheses from a set of assumptions. The hypotheses to be derived are (1) that less risk is preferred to more risk and (2) that a family with a high income level is more willing to take a risk than a family with a low income level. The assumptions from which the hypotheses are derived are (1) the utility of income is cardinally measured, (2) the total utility increases as income increases, and (3) the marginal utility decreases as income increases, but at a

decreasing rate (Freedman and Savage, 23).

According to the assumptions, we can draw a utility curve, which is shown in Figure 3.6. It is concave to the Y axis. It rises fast at first, but the rate of increase becomes less as income goes up.

Suppose families A and B are considering the same bet. The bet would give them the expected value of payoff E with a certain degree of uncertainty. Let us assume a simplified case in which the bet has only two outcomes, i.e., (1) the outcome which brings to the participants payoff $(E + d)$ at a $1/2$ chance, and (2) the outcome with payoff $(E - d)$ at a $1/2$ chance. In this simplified situation, uncertainty is measured by the size of d .

a. Greater risk versus less risk First, we want to compare three different situations from which family B would receive equal average expected income; (I) with zero uncertainty, namely, the outcome is single valued, (II) with the dispersion of payoff d , and (III) with dispersion d' .

Family B's utility under situation (I) is equal to $Y_B H$. Under the assumption of cardinal utility, its utility under situation (II) is equal to $Y_B H'$. Comparing these two values,

$$U_B(I) > U_B(II)$$

Let us define utility loss due to uncertainty under situation

(II) as

$$L_B(II) = U_B(I) - U_B(II).$$

Then

$$L_B(II) = Y_BH - Y_BH' = HH'.$$

Under uncertainty situation (III),

$$L_B(III) = HH''.$$

Comparison on the graph shows

$$L_B(III) > L_B(II)$$

Therefore, as the risk becomes greater, the family's utility decreases (utility loss increases). In other words, less risk is preferred to greater risk.¹

b. High income family versus low income family The same process of analysis shows us,

$$L_A(II) = MM'.$$

From assumption (3), the utility curve of income has less curvature over range $(Y_A - d, Y_A + d)$ than over range

¹However, this does not hold true over a range where the marginal utility of income increases as income goes up. Although this is a very unlikely situation within the income range we are interested in, greater risk is preferred to less risk in this case.

$(Y_B - d, Y_B + d)$. Thus,

$$MM' < HH'$$

$$L_A(II) < L_B(II).$$

This means, given the same average expected payoff with the same degree of risk, utility loss due to uncertainty is greater for the low income family than for the high income family.¹ In other words, the former is less willing to bear the risk than the latter.

E. Managerial Ability and Entrepreneurial Information Search Activities

1. Managerial ability and farm size

It is hypothesized that the operator's managerial ability and farm size are directly related.

A linkage between them is found in the process of capital accumulation and factor acquisition by the operator. An operator (A) who has a high level of managerial ability can realize the greater marginal value productivity for input factors than another operator (B) with inferior ability. It will place operator A in a favorable position in acquiring additional input factors at factor markets because he can bid higher prices for the factors. This holds true whether he desires to obtain capital, land, or labor.

¹It is assumed here that both families have the identical utility curves of income.

Another linkage may exist. Suppose two operators initially had equal potential ability with respect to management, both in terms of genetic factors and educational backgrounds. Suppose operator A started his farming on a larger farm than B because of inheritance. It is expected that the large farm needs a greater amount and better quality of management than the small farm. Operator A, through a greater need to improve the quality of his management input, tends to invest a greater amount of his resources into his managerial ability in the form of further education and training, formal or informal. Another possibility which is similar to the second case is that an operator who was born of a wealthy family and inherited a large farm may have received a higher level of education than he would have done if he had been born elsewhere in a poor family.

Through either of these linkages, we can expect that the operator of a large farm in general has better managerial ability than that of a small farm.

2. Return to information search activities and farm size

The operator's information search activities are undoubtedly an important part of his management. The search for opportunities to increase profit is the most essential part of the operator's entrepreneurship. As discussed in detail in chapter V, it plays an extremely important role in the farm firm's adoption of technological improvements.

Return to information search activities is defined as a net increase in the farm's income which is attributable to its improved knowledge. In other words, return to a certain amount of information search activities is the difference between the income obtained under the improved knowledge situation due to the additional information and the income that would be obtained if he made his decision regarding the improvement without this additional information. In reality, the return to information search arises either in the form of a reduction in errors of judgement or in the form of the discoveries of better ways of production. Both contribute to more rational decision making.

Our hypothesis is stated as follows: For a given amount of resources invested in information search activities, the operator of a large farm tends to obtain greater return than the operator of a small farm.

Our hypothesis is illustrated in Figure 3.7. Y denotes total return to information, and I denotes investment in information search. Subscripts A and B show two farms of different sizes. It is assumed Y is an increasing function of I .

Why is A's return to information search greater than that of B? First, the amount of information or knowledge one can obtain from a given amount of resources in the search is greater for farm A than for farm B. Second,

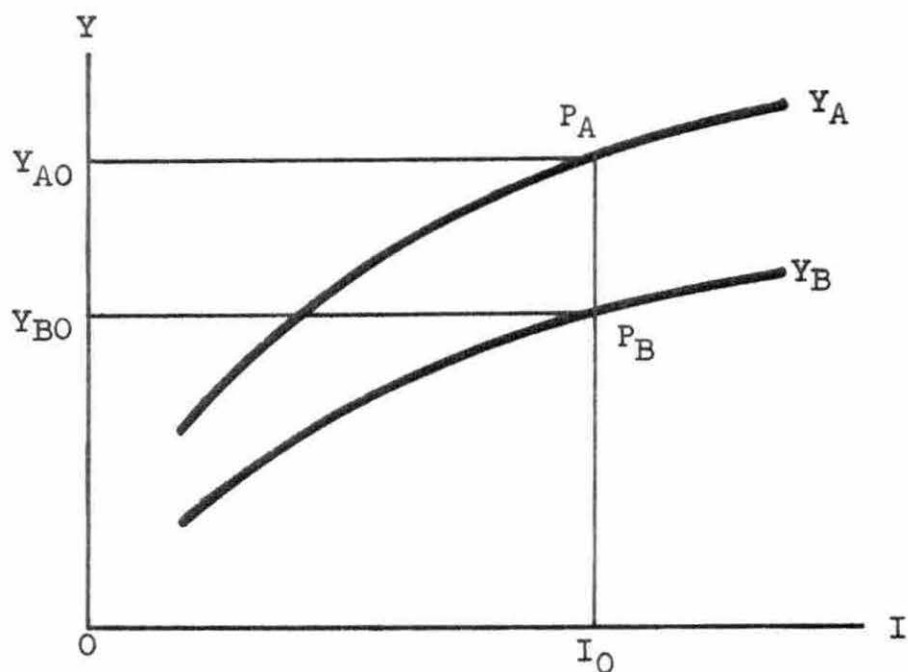


Figure 3.7. Differential returns to investment in information search activities on large and small farms

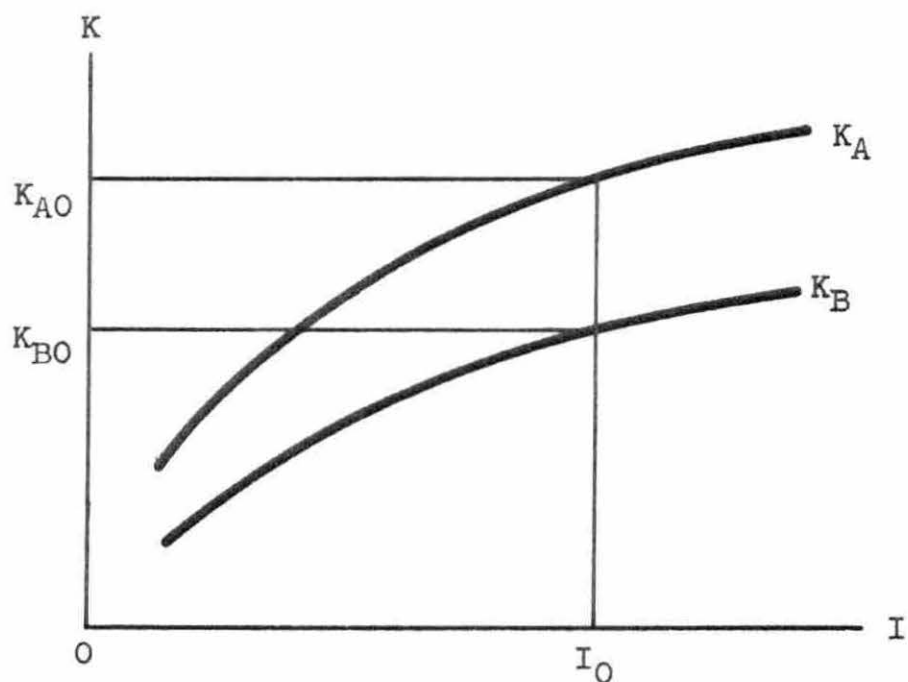


Figure 3.8. Relationship between investment in information search activities and information obtained on large and small farms

operator A's ability to analyze data and to reach more rational decisions are greater than that of operator B. Both notions are based on our hypothesis that operator A has a higher level of managerial ability than operator B, which is discussed in subsection 1.

First, operator A tends to obtain a greater amount of knowledge regarding the improvement from a given amount of resources invested in information search. This is because operator A probably has closer contacts with extension agents and other sources of information. Geographically and socially wider contacts help him obtain information more readily. Also, his ability to understand the information is probably greater than operator B. Second, let us suppose A and B have obtained the same amount of information. With a higher level of mental ability, operator A is expected to have greater capability to analyze and evaluate the possible outcome of the alternative courses of action. He is probably quicker in analysis, more accurate in evaluation, and more logical in reasoning. Therefore, we can expect that A obtains greater return to a given amount of information.

Figure 3.8 shows relationship between investment in the search (I) and the level of knowledge the operators reach. K_A and K_B denote knowledge level of both operators. Starting from a given amount of investment I_0 , the operators obtain information equal to K_{A0} and K_{B0} , respectively. Figure 3.9

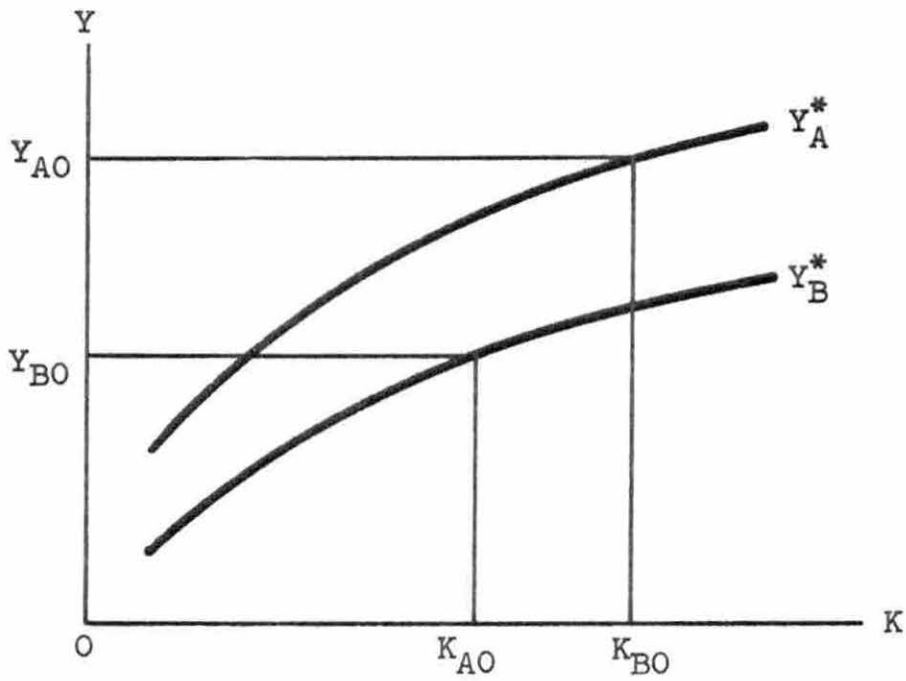


Figure 3.9. Relationship between the quantity of information obtained and return to information

show the hypothetical relationship between K and Y . Curves Y_A^* and Y_B^* are total return to knowledge K . Y_A^* is higher than Y_B^* over the entire range. Corresponding to K_{A0} and K_{B0} obtained in Figure 3.8, we can find out the total returns to investment I_0 of both operators at Y_{A0} and Y_{B0} , respectively. Connecting I_0 and Y_{A0} in Figure 3.7, Y_{B0} , points P_A and P_B are obtained. Moving I through the range, we obtain our hypothesized curves of Y_A and Y_B .

IV. NATURE OF TECHNOLOGICAL CHANGE IN AGRICULTURE

A. Changes in Agricultural Production¹

Recent changes in agricultural production in the industry as a whole are summarized in Tables 4.1, 4.2, and 4.3. Figures in these tables show us how the industry has changed with respect to inputs and outputs.

First, total output has increased at a substantially higher rate than total input. As a result, output per unit of input has continuously increased (Table 4.1).

Second, when inputs are broken down into categories, marked changes can be seen. Farm labor has declined. Its decline has been particularly rapid since 1940. Capital inputs have increased sharply. Machinery and power are the most rapidly increasing items among capital inputs. On the other hand, farm buildings stayed rather stable. Land input increased slightly at first but started declining after 1930 (Table 4.2).

Third, the characteristics of farms as production units have changed (Table 4.3). ". . . the number of acres one worker can handle increased by 150% from 1910 to 1960 (64 to 163) and by 70% from 1940 to 1960 (96 to 163). Mechanization has allowed each worker to handle more acres The amount of capital in relation to each worker has increased

¹Both text and figures are based on and adapted from Heady *et al.* (32, pp. 16-20).

Table 4.1. Sources and annual rates of change in output, inputs, and productivity, United States agriculture, selected periods^{a, b}

Period ^c	Change in output attributable to change in		Average annual rate of change in		
	Inputs (percent)	Productivity (percent)	Output (percent)	Inputs (percent)	Productivity (percent)
1870-1911	72	28	2.45	1.77	0.67
1911-1920	129	- 29	.70	.89	-.19
1920-1939	16	84	1.08	.17	.91
1939-1945	34	66	3.05	1.04	1.99
1945-1950	49	51	.81	.40	.41
1950-1956	- 9	109	1.89	-.17	2.06
1939-1956	22	78	1.98	.42	1.55
1911-1956	31	69	1.34	.41	.93
1870-1956	56	44	1.86	1.05	.80

^aSource: (46).

^bBased on indexes with 1947-1949 = 100.

^cThe beginning and ending year of each period (except the year 1870) is the midyear of 3-year averages.

Table 4.2. Percentage change in major categories of inputs for selected years, 1910-1960, United States (1947-1949 = 100)^a

Resource (input) category	1910	1920	1930	1940	1950	1960
Farm labor	135	143	137	122	90	62
Machinery and power	28	44	55	58	118	142
Farm buildings ^b	99	116	111	98	106	128
Fertilizer and lime	20	28	36	48	118	192
Tractors	-c	9	32	55	119	133
Combines	-c	1	12	37	137	205
Cornpickers	-c	-c	17	36	151	251
Feed, seed, and livestock purchased	22	32	37	63	101	149
Miscellaneous capital operating items	71	85	96	93	108	138
Cropland	87	95	103	100	100	92

^aSource: (32, p. 18).

^bFarm buildings are based on census enumerations and include the farm dwelling.

^cLess than one percent.

Table 4.3. Magnitude of the farm labor force, land, assets, and related resource quantities, 1910-1960, United States^a

Item	1910	1920	1930	1940	1950	1960
Work force (mil.)	13.6	13.4	12.5	11.0	9.9	7.1
Man-hours used (bil.)	22.5	24.0	22.9	20.5	15.1	10.3
Total land in farms (mil. acres)	879	956	989	1,060	1,159	1,158
Acres per worker	64.6	71.3	76.5	96.4	117.1	163.1
Value of production assets						
Current dollars	- ^b	- ^b	- ^b	38.7	95.9	156.8
1947-1949 dollars	- ^b	- ^b	- ^b	83.3	95.9	107.8
Value of productive assets per worker (\$)						
Current dollars	- ^b	- ^b	- ^b	3,413	9,625	21,235
1947-1949 dollars	- ^b	- ^b	- ^b	7,347	9,625	14,599
Capital input per unit of labor input (\$)	.87	1.00	1.17	1.41	2.41	3.96

^aSource: (32, p. 19).

^bNot available.

even more rapidly than has the acreage of farm land. Capital input per unit of labor input more than doubled between 1940 and 1960 (\$1.41 to \$3.96) while the value of capital per worker increased nearly sevenfold (in current dollars, \$3 thousand to \$21 thousand). With further economic development, capital inputs are expected to increase still more in relation to labor inputs" (Heady et al., 32, p. 19).

Technological change is not the only factor which has caused these changes. They are also the result of changing demand-supply relationship both in factor and product markets due mainly to the nation's economic growth, and of capital accumulation in the nation, in the industry, and in the individual farm firms. Technological change, however, appears to have played a crucial role in inducing these changes. Its effects are described in detail in the following sections.

B. Effects of Technological Change on the Individual Farm

1. Factor substitution and farm firm

It has been stated that technological change at the individual farm level is the process in which a new input is substituted for an old one. Some examples of substitution are described here.¹

¹Technological changes in recent U.S. agriculture are summarized in (Heady et al., 32, pp. 53-64, 68-87; Smith and Christian, 62, pp. 152-195).

a. Crop production Genetic, physiological and biochemical improvements are one form of input substitution. Higher-yielding crop varieties, improved chemical fertilizers and new forms of chemicals such as insecticides, pesticides and herbicides--all these new inputs have been substituted for older ones. Its direct effect has been a rapid increase in per acre crop yield. This causes the secondary factor substitution. As the result of increased per acre yield, substitution of capital inputs for land input takes place because fewer acres of land are needed in order to produce a given amount of output. They are also substituted for labor input. As per acre yield goes up, labor needed in handling the increased output may increase. But total man-hours of labor are likely to increase at a substantially lower rate than that of yield increase. Less man-hours of labor, therefore, are required for the production of one bushel of a crop.¹

Large, improved tractors and field machines replaced, first, horse drawn equipment and, then, old types of tractor drawn machinery. Its secondary effects have been (1) to replace horse power by machine power and release a sizable amount of land needed for feeding horses, and (2) to sub-

¹This secondary substitution does not necessarily mean that land and labor are actually replaced from the farm. It only means that the marginal rate of substitution of capital for land and labor increases.

stitute machine power for manpower, as it makes it possible for a worker to handle a larger number of acres.

b. Livestock production First, genetic, physiological, and biochemical improvements have been major factors contributing to increased feed efficiency, in eggs laid per hen, pigs saved per sow, etc. Improvements took the form of substituting, for example, new "feed" such as antibiotics and trace elements, new breeding stock, etc. (32, pp. 57-58). Secondary substitution takes place between capital and labor.

Second, rapid improvements in equipment have contributed to a remarkable increase in the number of animals or birds one worker can take care of. The trend is apparent in the poultry industry. It also seems to be occurring in cattle and hog production, too. Its secondary substitution takes place between capital input in the form of livestock and equipment and labor input.

2. Cost reduction

Cost reduction due to technological change was discussed in chapter II. It was stated that a new form of input is introduced and substituted for another because the ratio of the marginal value productivity of the new input to that of the old one is greater than the price ratio of these two. It was also shown that total outlay in the production of a given amount of output decreases or the

amount of output produced from a given outlay increases. This leads to a reduction in the average cost of producing one unit of output.

This is clearly the case in agriculture. For example, the increase in the value of output per acre of land far exceeds the increase in total outlay in the new forms of inputs. Similarly, improvements in machinery reduce the man-hour of labor required for one acre of cropland without increasing machine cost per acre substantially. Often, improvements take the form of larger tractors and other machines which enable a worker to handle a much larger acreage of land. If these machines are utilized to their full capacities, even machine cost per acre can decline because the larger outlays in these machines are spread over much larger acreage of crop land.

C. Biological and Mechanical Improvements

Discussions in section B suggests that there are two categories of technological change. One is what we called genetic, physiological and biochemical improvements. The other is improvements in machines, power, equipment and buildings. They are called biological and mechanical improvements (or innovations), respectively. Heady defines the terms as follows (30, pp. 818-819):

"By the term 'biological,' we will refer to those which have a physiological effect in increasing the total output (per acre, animal, unit of feed) from a

given land base. The term 'mechanical' refers to innovations as a machine which substitutes capital for labor but does not change the physiological outcome of the plants or animals to which it may apply."

He also states:

"Many mechanical innovations also have a physiological effect in increasing timeliness of operations or on soil structure or may otherwise directly affect the plants or animals."

Although they have common characteristics, i.e., factor substitution and cost reduction, the mechanism by which inputs are substituted or costs are reduced are quite different between the two categories of improvements. These differences are described in this section.

1. Factor substitution

Factor substitution associated with biological improvements typically takes place between inputs which perform rather similar functions in production. Improvements in fertilizer, feed and seed varieties are good examples. Although the secondary substitutions are somewhat different (substitution between capital and land, or between capital and labor), they do not seem to cause noticeable impacts on the farm because an increase in the total outlay in these capital inputs is not large.

Factor substitution takes place between capital inputs of similar kinds due to mechanical improvements. An old type of tractor is replaced by a new one, an old set of

dairy equipment by a new set, etc. The secondary substitutions takes place between capital and labor and between land and labor. Unlike the case of biological improvements, these secondary substitutions play an important role in changing the farms' input structure and farm size. This is discussed in subsection 2.

2. Cost reduction

a. Biological improvements The effect of biological improvements on costs and income is direct. It either increases output without increasing total costs, reduces total costs without reducing output, or increases both (but the rate of increase in output is greater than the rate of cost increase). Its new result is a reduction in the average costs per unit of output.

Since most of these cost items can be purchased and the output can be sold at market prices, the output increase increases income or profit directly without a secondary effect.

Another feature of biological improvements is that the income or profit increase is approximately proportional to the farm size or its original income. If the original per unit costs of output and its reduction due to the improvements are equal in two farms A and B (the large and small), and both have full equity and full ownership, then their income increase will be proportional to their farm size and

their original income level. It implies that income inequality increases in absolute terms and remains constant in relative terms, if the improvement is adopted simultaneously by both farms.¹ Even if these assumptions are dropped, the income gain is still likely to be approximately proportional to the farms' acreage size or the number of animals.

b. Mechanical improvements The effect of mechanical improvements on costs and revenue is indirect. The introduction of improved machinery and equipment reduces labor hours needed for the operation of a given farm size. But it may not increase the farm's income or profit immediately. Income would increase if total machine costs were to decrease due to, say, the adoption of a machine which is more compact and inexpensive but more powerful or efficient. In most cases, however, total outlay in machinery increases because new machines tends to be larger and more expensive.

Under these circumstances, cost reduction or output increase is realized only through indirect effects. The farm's income or profit increases through either of those processes listed below:

- (1) If a part of labor is hired, the farm can eliminate this hired labor and reduce its cost.

¹See the definition of income inequality (II, B, 3).

- (2) If there is no hired labor on the farm, one of the following has to take place.
- (a) Employment in nonfarm jobs
 - (b) Use of this released labor for other farm work which increases labor intensity--for example, better and more intensive care of livestock or crops in order to increase per acre yield or production per animal.
 - (c) An increase in farm size, i.e., the expansion of acreage size or the number of animals in order to employ the released labor at the same level of intensity.¹

Although the operator's or other family members' employment in nonfarm jobs may be important means of increasing income, particularly for those small farms which do not have enough resources to combine with the released labor, this problem goes beyond our interest here, i.e., income of farm origin. Within the farm there are two alternatives, (b) and (c). More intensive use of labor within the farm business would increase output to some extent. But con-

¹Another alternative is an increase in leisure. This would not increase family income, but it may contribute to an increase in family welfare.

sidering the probable rate of decline in productivity with more intensive use of labor in most farm situations, this alternative is likely to be a less effective way of increasing income than farm expansion.

If the adoption of an improved machine were to reduce the need for labor in the farm business by a half and if the farm could increase its size to the extent that the released labor is fully re-employed, then it can double its size and output. In order to expand size, the farm would need to acquire additional inputs. It has to increase its acreage or the number of animals either by means of purchase or lease. It may have to make additional investment in machinery and equipment. Doing so increases the farm's total costs in the form of rent and interest. But if the increase in total revenue is greater than increase in costs, the farmer's income will increase.

D. Adoption of Technological Change and its Implication on Income Distribution

It was suggested that technological change categorized as a biological improvement increases farm income by an amount nearly proportional to farm size. Income inequality will increase in absolute terms since the large farm will experience a bigger increase than the small farm. However, if there are some who adopt it earlier than the others, differential income effects occur between the early

and late adopters, in addition to the redistribution effect of the improvement itself. The farm's adoption behavior, which is discussed in chapter V, is of crucial importance in determining the income distribution effect.

The effect of mechanical improvements appears to be more complex. The farm's adoption behavior in relation to the operator's knowledge, skill or mental ability is undoubtedly important. But additional consideration appears to be necessary in case of mechanical improvements. First, we have to examine its effect on cost economies in relation to farm size. Second, the adoption of these improvements is closely associated with farm size expansion. Those who are able to expand will gain and those who are not will lose. These questions will be examined in chapter VII.

V. ADOPTION OF TECHNICAL IMPROVEMENTS--A MODEL ANALYSIS

It has been suggested that technical improvements, if adopted by all farms, have a certain income redistribution effect. It was also suggested that different adoption behavior among farms may have an additional redistribution effect on farm income. Redistribution takes place between earlier and later adopters. The possibility exists that there is a wide difference among farms in the time of the adoption of particular improvements. As described in detail in chapter VI, this hypothesis is strongly supported by numerous adoption studies made by rural sociologists.

It might be assumed that a particular technical improvement tends to be adopted first by those who benefit most and last by those who benefit least. But the profitability of the improvement is not the only determinant of the farm's adoption behavior. Other factors come in because the profitability of adopting the improvement involves a great deal of uncertainty particularly in the early stage of its diffusion. Those who can obtain the most complete information, those who can make the most accurate assessments of its profitability, and those who are most willing to run a risk in order to take advantage of an opportunity to increase their income are likely to be the first to make the adoption.

A person's ability to locate greater profit opportunities and to introduce them into his own firm is called

"innovativeness." This is an important function of entrepreneurship. Its importance in the performance and growth of industrial firms has been repeatedly emphasized. Under rapidly changing technological and economic conditions, we can imagine that "innovativeness" plays a crucial role in farm firms, too. Adoption studies suggest that there are wide differences in the operators' "innovativeness" among farms. The objective of our analysis in this chapter, therefore, is to examine the relationship between farm size and the innovativeness of the farm operator, and to relate it to the income redistribution effect of technological change through adoption behavior.

Adoption decisions are made after a process of seeking information related to the improvement, and then evaluating the possible outcomes of its adoption. This whole process is called the entrepreneurial "information search activities."

Information search activities have three major economic functions.

1. Discovering new income opportunities.
2. Achieving a higher level of optimality in the adoption decision.
3. Reducing uncertainty over the expected return to the adoption.

Discovery of new income opportunities may be included in the second function because discovery itself is nothing but an

act of obtaining certain information about the improvement. The second factor contributes to increased income because it reduces losses arising from the operator's wrong judgement about the profitability of the improvement or about the most profitable level of adoption (i.e., the level of investment in adoption). The third factor, i.e., a reduction in the operator's subjective uncertainty, contributes to prompt adoption decisions.

A. Hypothesis

Our major hypothesis in this chapter is as follows:

"Large farms tend to be the earlier adopters of improved techniques, and small farms tend to be the later adopters."

The factors contributing to earlier adoption by the large farms than the small farms are as follows.

1. Return to the adoption itself tends to be greater for the large farm (IV, C, 2).¹
2. The large farm is more willing to participate in information search activities and to invest in future income opportunities than the small farm (III, C, 4).
3. The operator of the large farm tends to obtain a greater amount of information about the improvement

¹Numbers in parentheses show chapter, section and subsection in which these attributes of large and small farms are described in detail in this thesis.

than the operator of the small farm for the same amount of time and other resources spent on information search. The former can also draw a more accurate estimation and more adequate decision than the latter based on the same amount of information (III, E).

4. The large farm is willing to take a greater risk than the smaller farm when the expected value of return is equal for both farms (III, D).

B. Assumptions

1. General

a. Two typical farms (III, E) The behavior of two typical farms A and B are compared.

b. Two categories of investments (II, C, 2) Investments associated with technical change are divided into two categories, i.e., investments in "information" and in "adoption."

c. Risk aversion (III, D, 1) Farm A is more willing to take a risk than farm B. Its most convenient expression is given in Figure 3.5.

d. Independence of uncertainty associated with investment in adoption from the rest of the farm It is assumed that uncertainty over the expected return to the adoption and the operator's risk-bearing decisions are not influenced by the uncertainty which has existed in the farm before the

adoption of the improvement.

e. Investment and return (II, C, 2) It is assumed that a functional relationship exists between the size of investment in "adoption" and the expected return. Two cases are considered (III, C, 4). They are shown in Figure 3.5 and reproduced in Figure 5.1. The total opportunity costs of the investment are shown as a straight line OC. Per unit costs of investment are supposed to be equal for both farms. Vertical distances between the cost line and the individual output curves are net returns (Z) to investments in "adoption." They are shown in Figure 5.2. Case 1 is represented by identical return curves Z_{A1} and Z_B ; case 2, by Z_{A2} and Z_B . By our assumption, Z_{A2} and Z_B are geometrically similar. The ratio of their size is equal to the ratio of the size of two farms (r).

f. Single valued relationship between costs and returns Net return curves in Figure 5.2 are assumed to be single valued. Under this assumption, uncertainty arises because the operators do not exactly know the shape and location of this single valued return curve and he makes his expectation based on his imperfect knowledge.

2. Formulation of expectation and information search

a. Expectation of optimum investment level In Figure 5.3, a curve showing net return to the investment is drawn. The optimum level of investment is K_e . The farm operator is

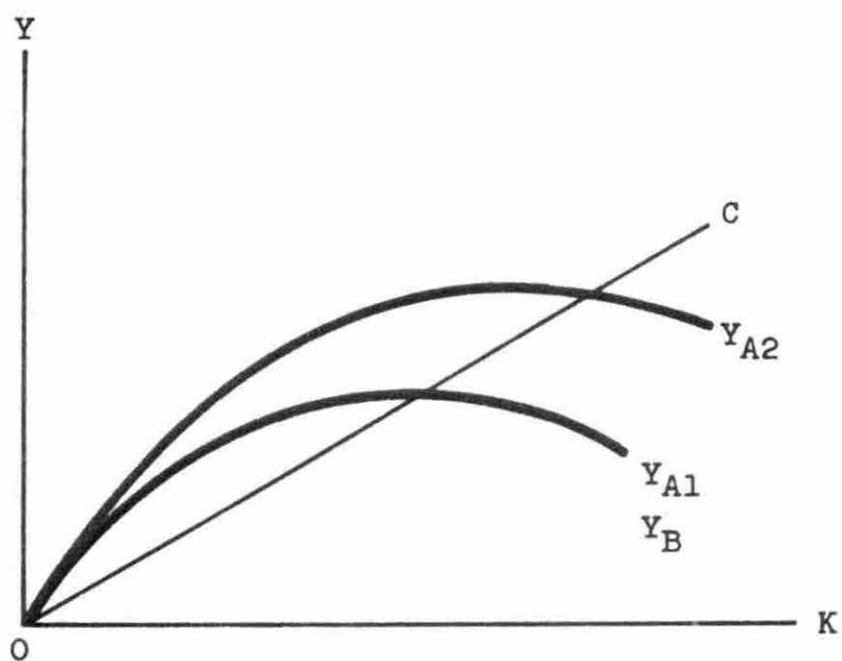


Figure 5.1. Gross returns to investment in adoption on large and small farms

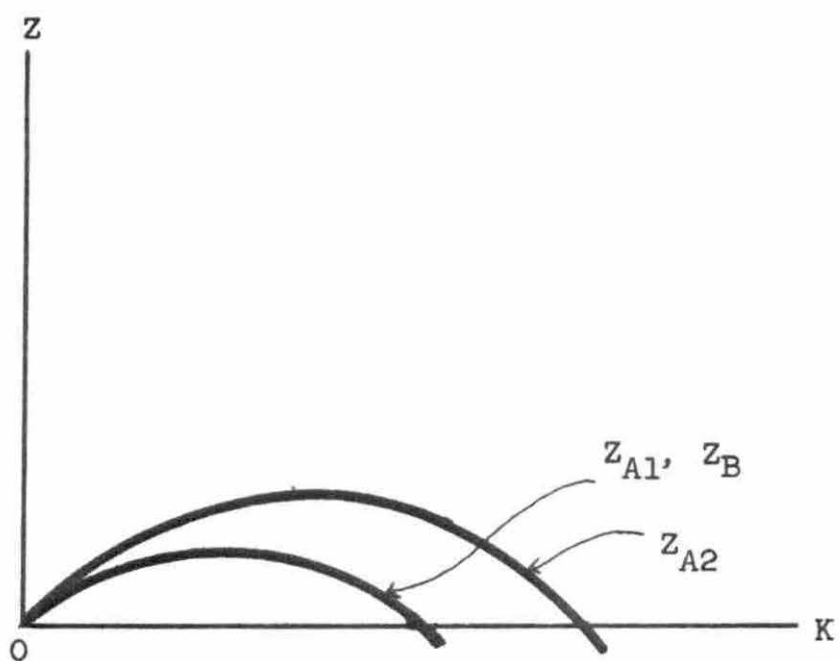


Figure 5.2. Net returns to investment in adoption on large and small farms

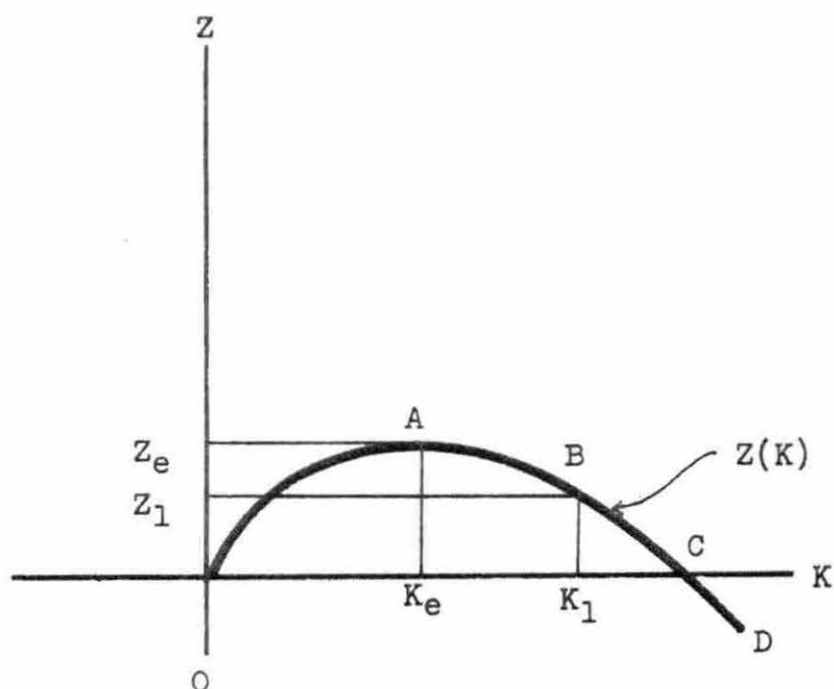


Figure 5.3. Level of investment and net return to adoption on small farm (farm B)

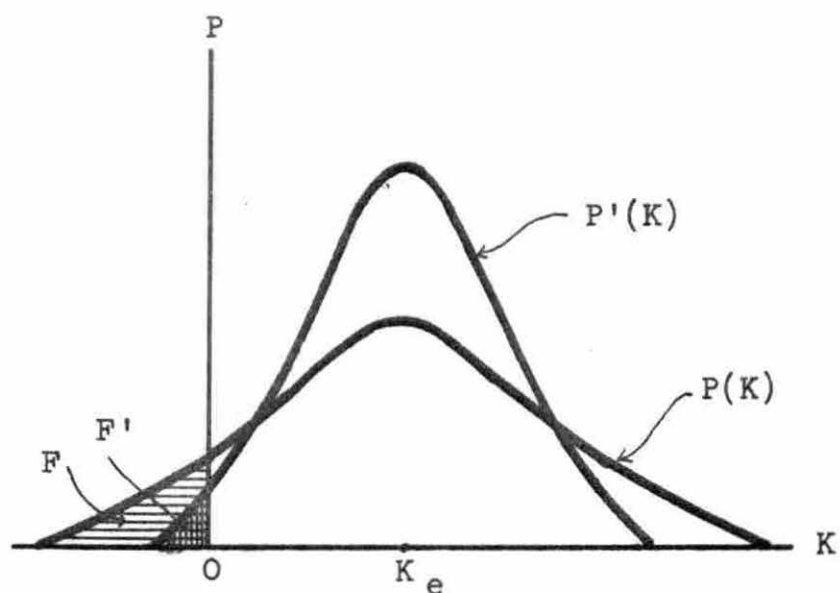


Figure 5.4. Probability distribution of small farm's expectation of the optimal investment level in adoption

assumed to make an expectation of K_e based on his information. Since he has only imperfect knowledge, his expectation errs. If his judgement, based on the information he has obtained, is that the optimum is at K_1 , he overestimates K_e by $K_1 K_e$. He loses a net return of $Z_e Z_1$ due to the deviation from the optimum. If his estimation of the optimum investment is K_2 , he obtains zero return and his opportunity loss is equal to $Z_e O$. Zero investment at 0 means he expects zero or negative net return, which leads to nonadoption.

b. Distribution of expectation It is assumed that the operator's expectation of K_e differs case by case because of difference in the information obtained in different search activities.¹ Taking many cases, his expectation of K_e is distributed as $P(K)$ in Figure 5.4. The distribution is assumed to have the mean value K_e and variance σ^2 . It is also assumed that standard deviation σ is a decreasing function of the quantity of information (n) on which the expectation is based. Then

$$E(K) = K$$

$$\text{Var}(K) = \sigma^2 \quad (1)$$

$$\sigma = G(n)$$

¹Information search activities can be compared to a sampling process; sampling from the population of information of the size N to obtain a sample of the size n (see discussion below).

and

$$\frac{dG}{dn} < 0 \quad (1)$$

Equations (1) indicate that the dispersion of his expectation around K_e becomes smaller as the quantity of information increases. For instance, curve P' shows a probability distribution of K resulting from a greater amount of information.

It is assumed that the shaded area of curve P represents the probability that he concludes it is not profitable to adopt the improvement. Negative values of K do not have any significant meaning.

c. Quantity of information Let us suppose that there exists an amount of information which gives the operator perfect knowledge of the improvement. Suppose this information can be divided into N small bits each of which contributes an equal amount of knowledge about K_e . The operator is assumed to obtain a sample information of size n which is a subset of the total information of size N, and to formulate his expectation based on this subset.

d. Cost of information Per unit cost and therefore the marginal cost of information is assumed to be constant for an operator at a given time. The cost, however, is assumed to be a decreasing function of (1) the operator's ability (y) to locate, understand, and analyze information,

and (2) time (t). We can write the total cost of information as follows:

$$c = n \cdot h(y, t)$$

$$\frac{\partial h}{\partial y} < 0 \tag{2}$$

$$\frac{\partial h}{\partial t} < 0$$

C. Difference in Adoption Behavior

Based on the series of assumption described above, a model is formulated in order to explain differences in adoption behavior between the two typical farms. First, net return to information search activities is analyzed in relation to the quantities of information obtained. Second, the relation between the degree of uncertainty and the quantity of information is examined. Third, based on the above analysis, possibility curves are constructed in order to describe the relation between the expected net return to technical improvements and its uncertainty. Fourth, combining the possibility curves with the operators' indifference maps that describe their risk bearing behavior, the levels of information search activities are determined. Fifth, the location of the equilibrium points on the indifference map also determines the time of adoption.

1. Information search and net return to "improvement"

Let us define the net return to an "improvement" as return to investment in a technological change. This includes both returns to investments in "information" and "adoption" (II, C, 2). This is the average value of the return the farm can expect as a result of an (imaginary) infinite number of trials of "sampling" information.

a. Farm B Let us take farm B, and draw its net return curve to the investment in "adoption." This is shown in Figure 5.3. By our assumption the farm tries to make an estimation of K_e . The estimates are assumed to have a distribution as shown in Figure 5.4. Based on n_0 quantity of information, this estimation is distributed as $P(K)$. n'_0 quantity ($n'_0 > n_0$) gives the estimation which is distributed as $P'(K)$. $P'(K)$ has a smaller variance σ'^2 than that of $P(K)$ (σ^2).

The left-hand side of the graph from the P axis shows nonadoption. Shaded areas F and F' are assumed to be equal to the probability that operator concludes that the adoption would result in a negative net return.

From Figures 5.3 and 5.4, we can obtain a probability distribution of the expected return Z. Based on n_0 quantity of information, the distribution looks as ABCD plus the probability equal to area E at $Z = 0$. Z_e is the maximum value that Z can take (Figure 5.5). The distribution based

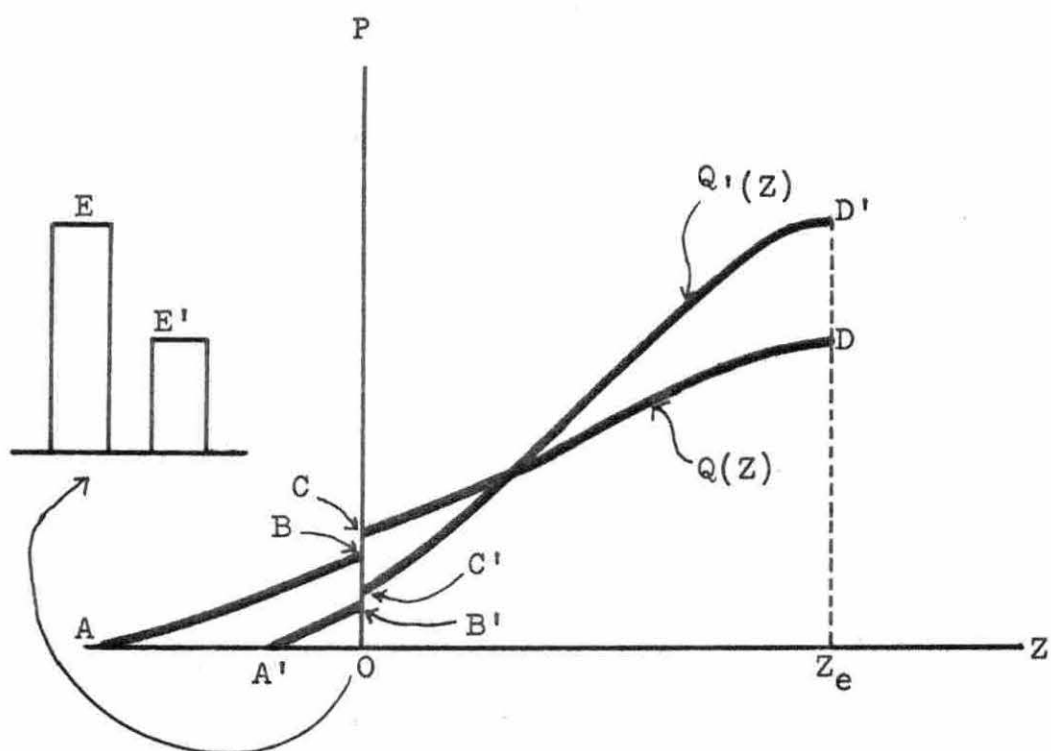


Figure 5.5. Probability distribution of net returns to adoption on small farm

on n_0' quantity of information becomes more concentrated near Z_e . It is shown as curve A'B'C'D' plus probability E' (at $Z = 0$). E' is smaller than E. These two distributions are identified by $Q(Z)$ and $Q'(Z)$, respectively.

The expected value of Z is the average net return farm B can expect to obtain from an adoption decision based on the operator's information. Hence,

$$W_0 = \int_{-\infty}^{Z_e} Z \cdot Q(Z) dZ$$

and

$$W_0' = \int_{-\infty}^{Z_e} Z \cdot Q'(Z) dZ$$

Points (n_0, W_0) and (n_0', W_0') are plotted in Figure 5.6. Moving n over the entire range, we can obtain the curve which shows the return to "improvement." This curve (identified by T_B) rises rapidly at a low level of n , indicating that the return to a given increment of information is high in this range. The curve becomes flatter as n increases, and never goes higher than Z_e . At an extremely low level of n , the farm may obtain negative net returns as shown in Figure 5.6, because the adoption can never be performed satisfactorily if it is based on such a limited amount of information.

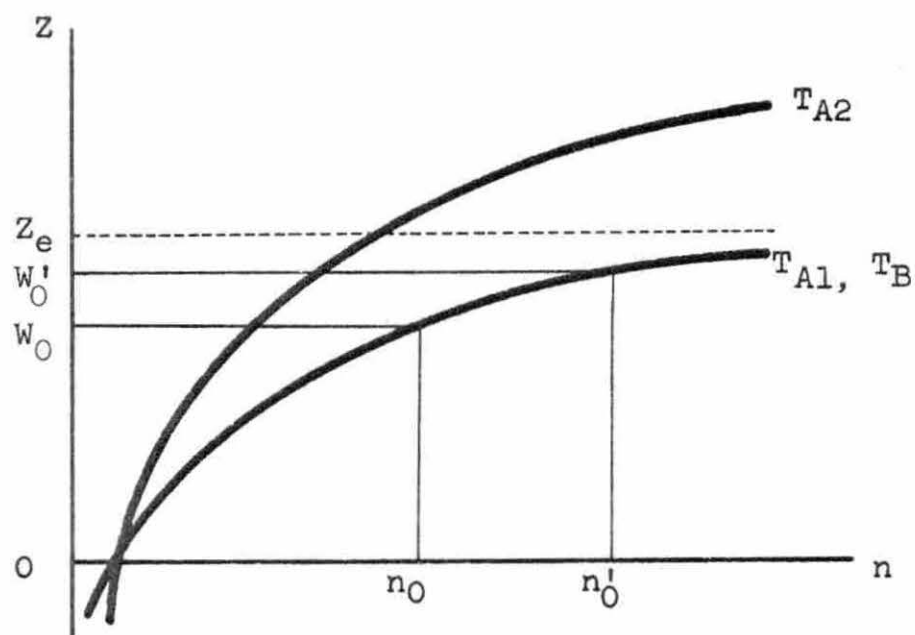


Figure 5.6. Expected net returns to adoption as a function of the quantity of information, large and small farms

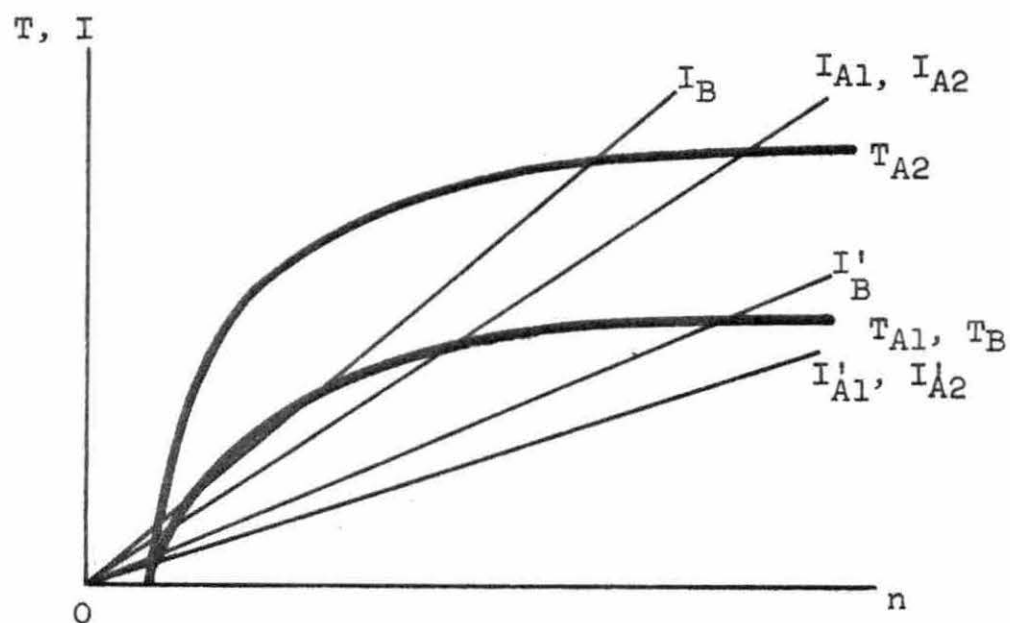


Figure 5.7. Expected net returns to adoption and cost of information, large and small farms

b. Farm A In case 1, the expected return curve of farm A is identical with that of farm B, because the original Z curves on these farms are identical. This curve is named T_{A1} . In case 2, it looks like curve T_{A2} shown in Figure 5.6. The vertical distance between T_{A2} and the n-axis is r times as much as the distance between T_B and the n-axis. This is so because Z_{A2} curve in Figure 5.2 is r times as large as Z_B .

c. Cost of information and "net return to improvement"
Curves T_{A1} , T_{A2} , and T_B are not the expected "net" return to the improvement because the costs of information search are not taken into account yet.

By our assumption, the total cost of information is proportional to the quantity of information, n. Per unit cost of information is assumed to be less for farm A than for farm B. Hence, we have the cost curves of information I_{A1} , I_{A2} , and I_B shown in Figure 5.7.

Vertical distances between T and I curves are equal to the expected net returns to investment in the "improvement." They are shown in Figure 5.8.

2. Information search and uncertainty

In our study, uncertainty is measured by the dispersion of the expected return (III, D, 1). This is measured by the standard deviation of curve $Q(Z)$ shown in Figure 5.5. As n increases, $Q(Z)$ is more concentrated around Z_e , thus

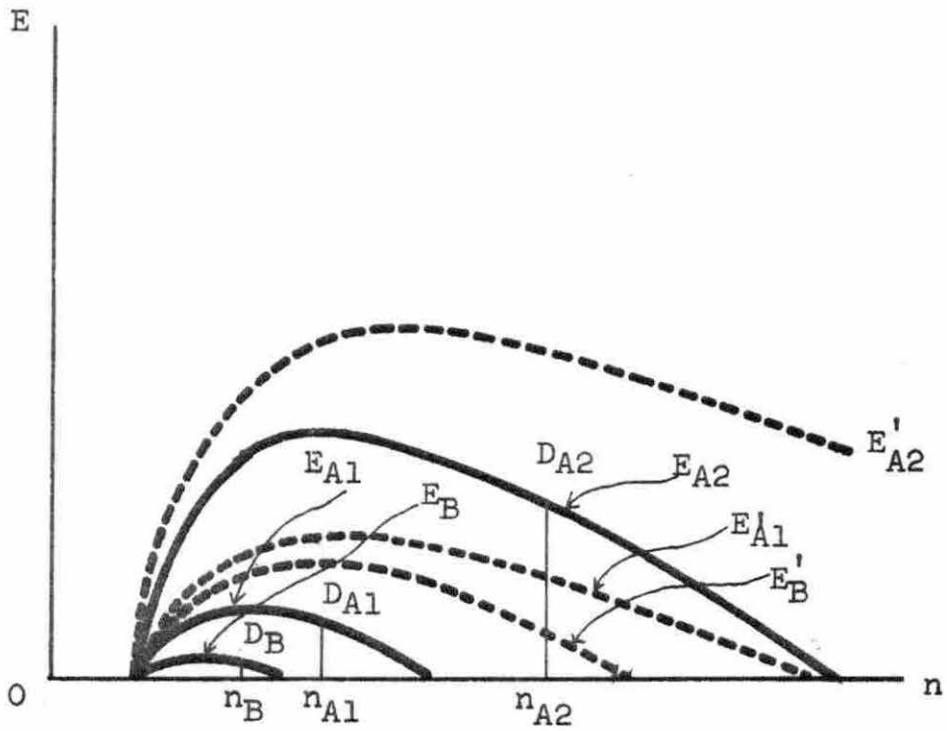


Figure 5.8. Expected net returns to improvement as a function of the quantity of information, large and small farms

reducing the dispersion (R). It is expected that R declines rapidly at a lower level of n and at a decreasing rate as n increases. This is shown in Figure 5.9. R_{A1} is identical to R_B and R_{A2} is r times as large as R_B because of our assumption on the total return curves shown in Figure 5.2.

3. Net return-uncertainty possibility curve

From Figures 5.8 and 5.9, we can draw a possibility curve that given the focus of possible combinations between the expected net return to the improvement and the uncertainty associated with it. This is shown in Figure 5.10. Farm A's possibility curves in cases 1 and 2 are V_{A1} and V_{A2} , respectively. Farm B's possibility curve is shown as V_B . Curve V_{A2} has the greatest horizontal distance from the R -axis among all curves, indicating that the expected net return is greatest. V_{A1} is also greater than V_B because of A's smaller per unit costs of information than that of B.

4. Equilibrium on indifference map

Since we have the net return-uncertainty possibility curves and since we know the farms' indifference curves that specify choice between these two factors, we can determine the equilibrium points for these farms in both cases 1 and 2. This is done by locating points where the possibility curves are tangent to one of the indifference

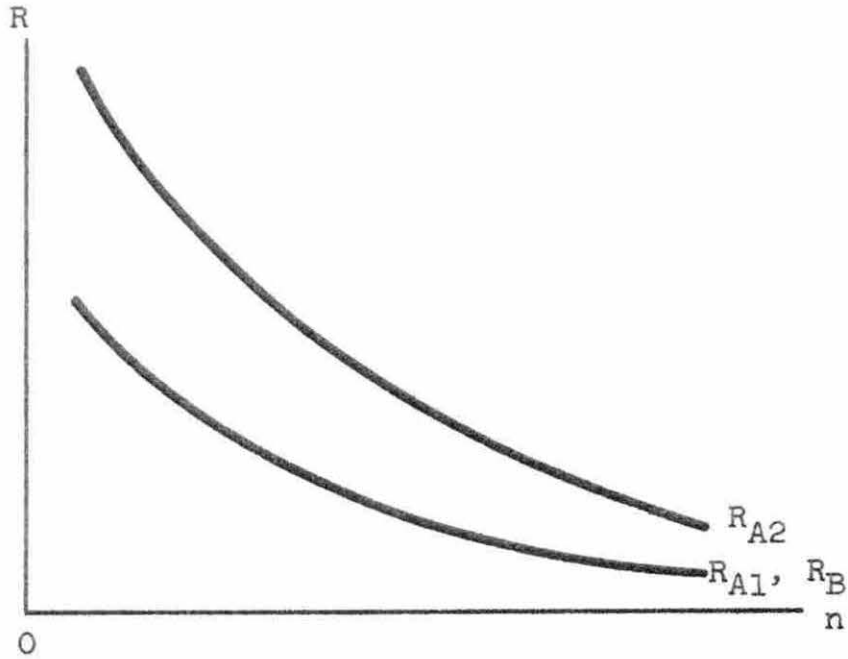


Figure 5.9. Uncertainty as a function of the quantity of information, large and small farms

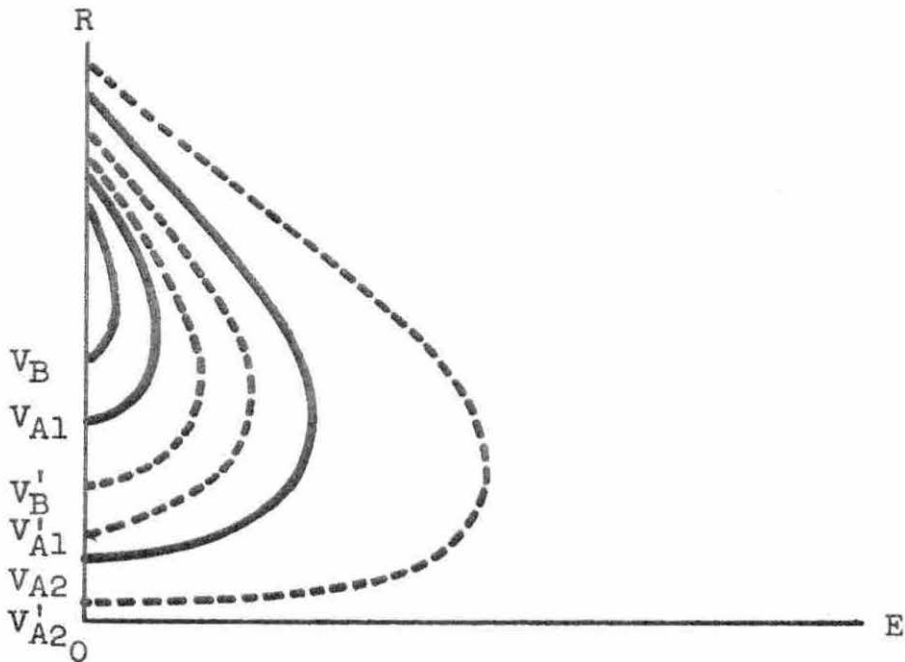


Figure 5.10. Possibility curves showing combinations of expected net returns to improvement and uncertainty, large and small farms

curves as shown in Figure 5.11. The equilibrium points are named D_{A1} , D_{A2} , and D_B , respectively. Tracing these points back in Figure 5.8, we can obtain the equilibrium quantities of information (n_{A1} , n_{A2} , and n_B , respectively). They indicate that farm A obtains a greater amount of information than farm B.¹ They also indicate that farm A obtains a greater amount of information in case 1 than in case 2.

5. Early and late adoption

Under the situation shown in Figure 5.11, farm B would not adopt the improvement. It has been stated that the operator refuses to make a bet if the return-uncertainty combination D_B is located above the zero-level indifference curve U_{B0} (III, D, 1). Farm B is placed in such a condition. On the other hand, farm A will adopt the improvement because both D_{A1} and D_{A2} are located below the zero-utility indifference curve U_{A0} . The end result is that the improvement is adopted by farm A but not by farm B.

How does operator B come to the adoption decision? He has to wait until evidence shows him more clearly that the adoption of the improvement is really profitable. Under

¹This is not absolutely true. Depending on the difference in the cost of information search and difference in the slope of the indifference curves between the farms, n_B could be greater than n_{A1} or n_{A2} . But as shown in chapter VI, it is generally expected that the large farm obtains a greater amount of information than the small farm.

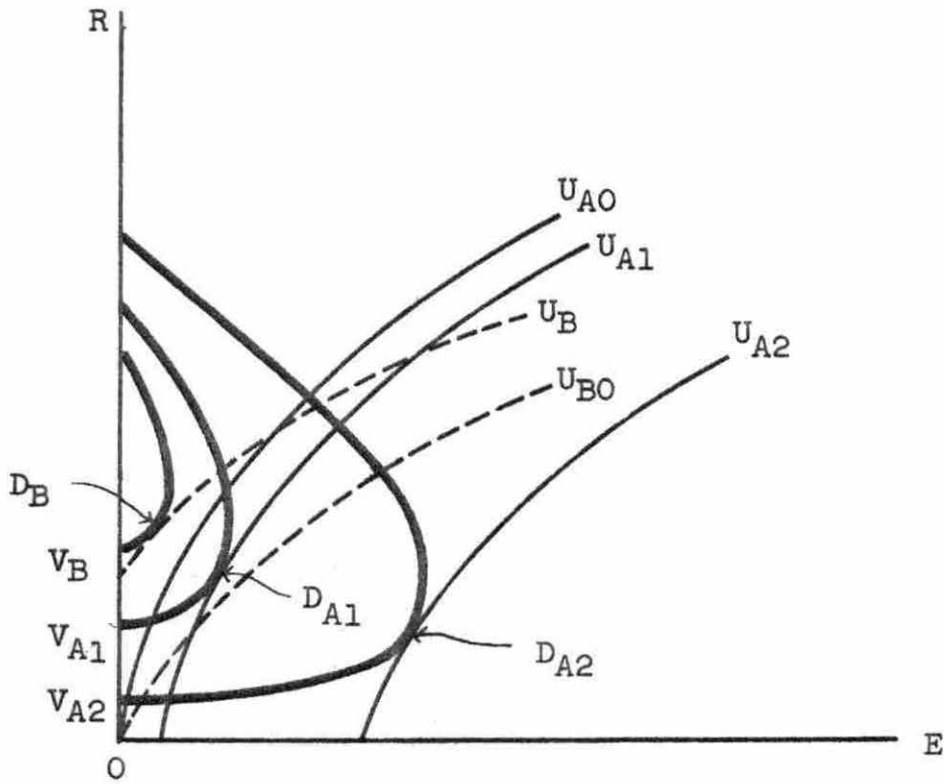


Figure 5.11. Large and small farms' adoption decisions at time t

our assumption, per unit cost of information decreases as time passes. This is because, as time passes, more accurate and convincing data are obtained more readily from persons such as his neighbors who have adopted the improvement or farm extension agents who have become better equipped with up-to-date information. This cost reduction, therefore, will lead to greater net return to "improvement" and reduced uncertainty because a greater amount of information will be obtained at the same cost the operator originally spent. He may finally be placed in a situation which permits him to make the adoption decision.

Suppose, at a later time (t'), the cost of information goes down by a half. This is shown by cost lines I'_{A1} , I'_{A2} , and I'_B in Figure 5.7. We can derive the net return-uncertainty possibility curves at time t' in the same manner as we did before. The process of derivation is shown successively in Figures 5.7, 5.8, 5.10, and 5.12. Only the second case is shown in Figure 5.12 in order to avoid a confusion in the graph. The farms are in equilibrium at D'_{A2} and D'_B , respectively. They end up with (1) a greater amount of information obtained, (2) reduced uncertainty, and (3) increased expected net return, compared with the initial situation at time t .

Farm B reaches the decision to adopt the improvement in this stage. However, farm B missed the opportunity to

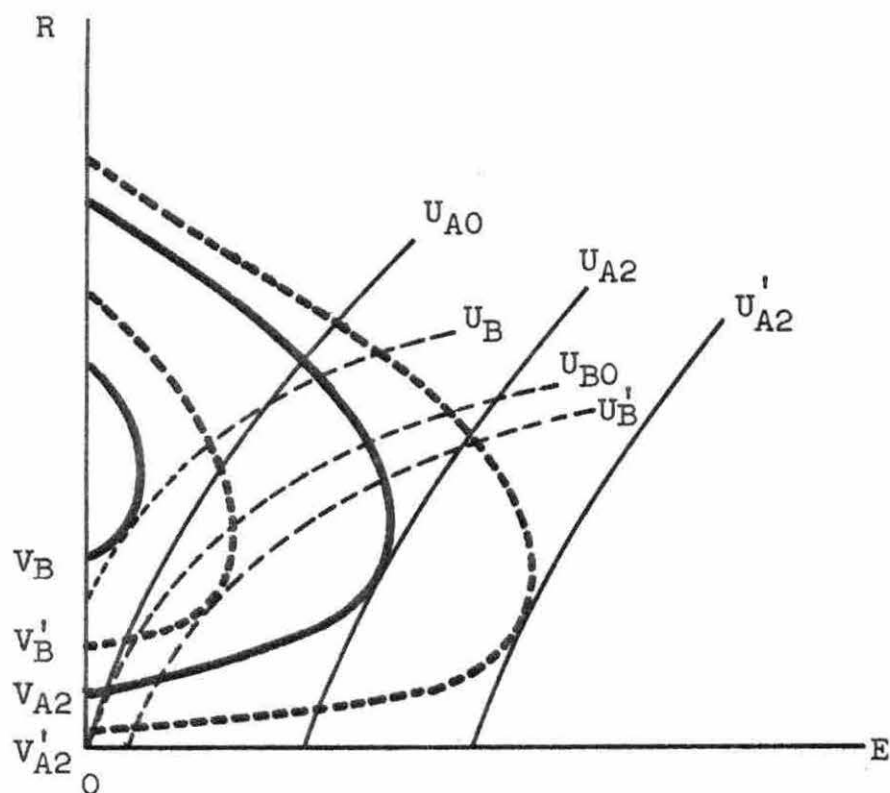


Figure 5.12. Large and small farms' adoption decisions at times t and t'

increase its income during the period between t and t' . The opportunity loss will be greater, the longer his adoption decision is delayed.

Discussions in this section show us that the difference in time of adoption between farms A and B is greater as (1) the difference in relative net return to "adoption" is greater, (2) the difference in per unit cost of information, i.e., the operator's ability to locate, understand, and analyze related information is greater, (3) the difference in their willingness to run a risk is greater, and (4) the reduction in cost of information associated with time is slower.

D. Additional Considerations

There are other relevant factors which have not been discussed in this section C because they could not be included in our model. Some of these are thought to have important effects on the operator's adoption behavior.

1. Reduction in investment level due to uncertainty

According to studies of risk and uncertainty, a farm tends to limit its investment to a level lower than the optimum if it is faced with an uncertainty situation (Kalecki, 41; Johnson, 39, pp. 57-59, 61-71).

Since the adoption of technical improvements is one form of investment decision, the level of investment in

adoption also may be influenced. This reduction of investment below the optimum level may be another source of lower farm income.

It is argued that this deviation from the optimum investment increases as the amount of investment increases. In case 2 of the comparison between farms A and B (see section C), farm A's optimum investment is greater than that of farm B. Therefore, A may deviate downward from K_e to a greater extent than B.

However, there are some factors that may offset this effect. First, due to a greater amount of information obtained by A, subjective uncertainty may be less for A than for B. Second, operator A is more willing to bear a risk than operator B. These factors contribute to farm A's improved optimality relative to that of farm B.

We are unable to specify whether farm A's deviation from the optimum is greater or less than that of farm B. We can only say that A's relative optimality increases compared with that of B as (1) the ratio of the quantity of information available to farm A increases relative to that available to farm B and (2) the difference in their willingness to bear a risk becomes greater.

2. Saving and investment behavior

It has been shown that the high income family tends to invest more than the low income family when the investment

yields equal rates of return on both farms (III, C, 4). This difference in investment behavior between the high and the low income farms tends to increase the difference in the time of adoption between the two. Investment difference takes two forms (II, C, 2). The high income farm is expected to invest more in information search activities and also in the adoption of the improvement itself.

Greater investment in information search increases the amount of information the operator obtains and reduces uncertainty more rapidly over time. Greater willingness to invest in "adoption" will contribute to the prompt adoption of the improvement. Thus, farm A's greater willingness to make these two categories of investment than that of farm B will contribute to an even earlier adoption by farm A relative to farm B.

VI. PARTIAL TESTS OF HYPOTHESES ON INFORMATION SEARCH AND ADOPTION

A. Hypotheses

1. Hypotheses to be tested

Discussions in chapter V can be divided into a series of subhypotheses to which we may apply empirical tests using the existing research data. These subhypotheses are as follows:

Subhypothesis 1. The operator of the large farm tends to invest greater amounts of resources in his information search activities than the operator of the small farm.

Subhypothesis 2. The farm which has invested a greater amount of its resources in information search activities tends to evaluate the profitability of an improvement more accurately and to reduce its uncertainty to a greater extent than the farm which has invested less.

Subhypothesis 3. More accurate evaluation and reduced uncertainty tends to promote the early adoption of the improvement.

Subhypothesis 4. The large farm tends to receive greater net return from the adoption of the improvement than the small farm. In other words, the capacity of the former to absorb investment in new techniques profitably is greater than for the latter (due to the difference in resources which can be combined with the new investment).

Subhypothesis 5. As a result, the large farm tends to be an earlier adopter of the improvement and the small farm tends to be a later adopter.

Subhypothesis 6. The large farm tends to be an earlier adopter consistently in response to a series of technical improvements successively introduced in society, while the small farm tends to be a later adopter in most cases.

Tests of subhypotheses 2 and 3 are not easily made because they require evaluation of the expected net return to the adoption and its uncertainty. Therefore, the test is made in the form of a related subhypothesis.

Subhypothesis 2'. The farm which has invested the greater amount of resources in information search activities tends to be an earlier adopter of the improvement.

Subhypothesis 4 also involves difficulties. A major trouble is that available adoption studies do not investigate the effect of the adoption on farm income or profits in most cases. Although there are some studies which attempted to examine the economic as well as noneconomic attributes of various types of improvements and their relation to "acceptability" to farms, these studies are not concerned with differential income effects between large and small farms (20, 21, 22, 43). This subhypothesis, therefore, is not examined. Four subhypotheses, i.e., 1, 2', 5, and 6, are examined using these adoption studies.

2. Nature of adoption studies

A great number of adoption studies have been made by rural sociologists. Their major concern, however, has been focused on such variables as the social status of adopters, the communication patterns of information related to technical improvements, community structure, norms and so forth. Although a substantial amount of attention has been paid to such economic variables as farm size and income level, and their relation to adoption behavior, the scales used for these economic variables seem to be rather crude.

Despite these shortcomings, the studies appear to shed some light on our subhypotheses. First, the adopter categories have been well established in these studies so that the earlier and later adopters of a specific improvement are clearly defined. Second, the attributes of farms in each adopter category have been intensively investigated. Crude and limited as they are, we may be able to relate some of the economic variables to the farm's information search activities and adoption behavior.

3. Adopter categories

The farm's adoption behavior is usually described by the time of adoption. The adopter categories are understood to be successive parts of a continuum ranging from earliest to latest adoption.

Of a number of studies related to adopter categories,

Rogers' classification appears to be most systematic (54). He classified farmers into five categories on the basis of the relative time of adoption. The five categories are (1) innovators; first 2-1/2 percent, (2) early adopters; 13-1/2 percent, (3) early majority; 34 percent, (4) late majority, 34 percent, and (5) laggards; last 16 percent.¹

Our examination, however, does not require such a fine classification. Most comparisons of adopter characteristics are made between relatively earlier and later adopters.

4. Socio-economic status

"Socio-economic status," a measure often used by sociologists, appears to have a very close correlation with income level. Sewell's original socio-economic status scale (59), his short form (60) and its modification (Belcher and Harp, 3), all of which are used most often by rural sociologists, are based on the definition of socio-economic status by Chapin (11, p. 99).

"Socio-economic status is the position that an individual or a family occupies with reference to the prevailing average standards of cultural possessions, effective income, material possessions and participation in group activities of the community."

Although sociologists may employ these scales in order to indicate a social stratification among the members of

¹An overall picture of adopter categories is given by Rogers (55, p. 185, Table 6-4).

the community, it is our understanding that the measurements are made in such a way that the family's income level is fairly accurately reflected in them. It appears, therefore, that the relations between this socio-economic status and other variables approximate (at least indirectly) the relations between income level and these variables.

B. Farm Size and Information Search

Subhypothesis 1. The operator of the large farm tends to invest a greater amount of resources in information search activities than the operator of the small farm.

Most of the studies appear to support the hypothesis that there exists a correlation between socio-economic status and information search activities. If we are allowed to interpret this as showing a correlation between income level and information search activities, our subhypothesis is supported. As for the relation between farm size and information search, the first two of the three studies cited below support the hypothesis, while Photiadis states it is only partially supported. As a whole, there appears to be a distinguishable though not very clear relationship between farm size and the intensity of information search activities.

Lionberger (44) classified 279 farms into three categories according to their information sources. They were (1) users of county agents, (2) users of other institution-

alized sources,¹ and (3) users of no institutionalized sources. He found that "the nonuser group was most distinctive with respect to characteristics affecting the diffusion of farm information. They were much older . . . , smaller operators than those who used the institutionalized sources Gross farm income of nonusers were only about half as large as those of the users Also they were accorded a lower status in the community."

Coleman (13) used seven measures "as indicators of the extent to which Extension was reaching the people of the community, and the difference in the extent to which various groups and classes have been reached." He concluded, "The best educated persons and those of the highest socioeconomic status were most often reached. Operators of large farms were more often reached than small farms."

Photiadis (52) found that "social status is the only factor which is related . . . to both the seeking of contacts with agricultural agents and to the direct learning of agricultural technology The factors of net worth and money invested in livestock and machinery only partially support this hypothesis. This is the case because, although

1" . . . the Agricultural Extension Service, the vocational agriculture teacher and his staff, such government agencies as the Farmers' Home Administration, the Production Marketing Administration . . . and the Soil Conservation Service; bulletins . . ."

all the relationships which are involved in the testing of the hypothesis are positive as expected, most of them are not significant at the required level."

C. Information Search and Adoption

Subhypothesis 2'. The farm which has invested a greater amount of resources in information search activities tends to be an earlier adopter of the improvement.

Most research data show that there is direct relationship between information search activities and adoption behavior.¹ Havens summarized those studies which examined the relationship between personal and community characteristics and the rate of adoption (28). Of 18 studies which included "contact with information" as an independent variable, 17 show significant effect on adoption at the 5 percent level of significance.

Rogers (55, pp. 178-182) summarized those studies investigating differences in communication behavior between earlier and later adopters as follows:

1. Impersonal sources of information are more important than personal sources for relatively earlier adopters of innovations than for later adopters.
2. Cosmopolite sources of information are more important than localite sources for relatively

¹A few of such studies made in the earlier period were made by Gross (25), Fliegel (19), Lionberger (45), and Coughenour (15).

earlier adopters of innovations than for later adopters.¹

3. Earlier adopters utilize information sources that are in closer contact with the origin of new ideas than later adopters.
4. Earlier adopters utilize a greater number of different information sources than do later adopters.

To sum up, earlier adopters spend more time, look for information over wider geographical areas and social classes, and contact with a greater number of sources, than later adopters.

D. Farm Size and Adoption

Subhypothesis 5. The large farm tends to be an earlier adopter of the improvement and the small farm tends to be a later adopter.

The test of this subhypothesis is achieved by examining the economic characteristics of different adopter categories. A number of studies appear to support this hypothesis. Havens' summary (28) says that 27 out of 30 studies which include farm size as a determinant of adoption found it has significant effect on adoption. Likewise, all 21 studies found that socio-economic status was a significant determinant of adoption.

Rogers summarizes the existing studies as follows (55,

¹"Cosmopolite information sources are those external to a social system" (Rogers, 55, p. 179).

pp. 172-178): Earlier adopters (1) are younger in age, (2) have higher social status, (3) have more favorable financial position, (4) have more specialized operations, and (5) have a different type of mental ability than later adopters.

Although both summaries appear to provide fairly firm support for our hypothesis, one weakness of this type of study is that the causal relations can run both ways. High income and large size of operation may encourage earlier adoption as our hypothesis states. But high income might be, in part, a result of earlier adoption. As Fliegel suggests, "To resolve the problem of which is cause and which is effect, or whether the process works both ways, a study of the relationship between adoption and farm income over a period of time would be necessary" (18, p. 161).

This has been done in industrial research. Mansfield summarizes his study as follows (48, p. 130):

". . . in the period immediately before they introduced the innovations, there was no persistent tendency for the successful innovators to grow more rapidly than the other comparable firms. But in the period after they introduced the innovations, there was a considerable increase in the difference in growth rates between innovators and other comparable firms. In terms of short-term growth, the rewards for innovation seem to have been substantial, particularly for smaller firms."

This type of empirical study in agriculture, which is directly related to our hypothesis 4 but which has been excluded from our examination, would be quite useful, although it might require a substantial amount of time and

resources.

E. Consistency of Early Adoption

Discussion in section D leads us to an important question: Do the earlier adopters of one improved technique adopt others consistently earlier than the later adopter of that improvement? This may be true if there are common attributes related to the adoption of all improvements.

A study of innovation behavior in industry is suggestive. Its summary says (Mansfield, 48, pp. 169-170, 172):

" . . . given that two innovations occur within a few decades of each other, one can expect some positive correlation between how long a firm waits before introducing one and how long it waits before introducing the other. Thus, if two innovations are reasonably close together in time, there is generally some tendency for the same firms to be relatively quick--or slow--to introduce both.

" . . . Although there is some such tendency, technical leadership does not seem to be very highly concentrated Even if one firm was considerably quicker than another to begin using one innovation, the chance that it will also be quicker to introduce another innovation occurring only five years later is not much better than 50-50. Apparently, there is no particular group of firms that consistently exercises leadership of this kind and no particular group that consistently brings up the rear."

Rogers gives a summary of the studies on this question in agriculture. Although the evidence is not conclusive, it provides some support for the hypothesis. He states, "Some support for the consistency of innovativeness among farmers is provided by factor analysis of innovativeness . . .

Additional support comes from intercorrelations of items in innovativeness scales . . ." (55, p. 187, footnote).

VII. FARM FIRM GROWTH AND ITS EFFECT ON INCOME DISTRIBUTION

A. Technological Change, Farm Size and Income

In chapter IV (section C), it was suggested that an increase in the size of operation is the most effective means for the farm firm to reap the income gain made possible by the labor saving effect of mechanical improvements. In the first part of this chapter, the relationship between farm firm size and income is examined. We are particularly interested in the effect of technological change on the relation between size and income.

1. Farm size and income

Farm firm growth can be an effective means of increasing profit and income even in the absence of technological change. Suppose the long-run cost curve of a farm firm is horizontal as LAC_1 in Figure 7.1. With output price (p) higher than the average cost (c), an increase in output will increase the farm's net profit in proportion to its output size, as long as the price of output remains constant. If, instead, the cost curve slopes downward to the right (LAC_2), growth will contribute to profit increase to a greater extent. Income increases due to (1) increased income generating assets in the firm and (2) increased efficiency of resource use made possible by the increasing cost economies associated with larger size. In this case, the farm whose size is within

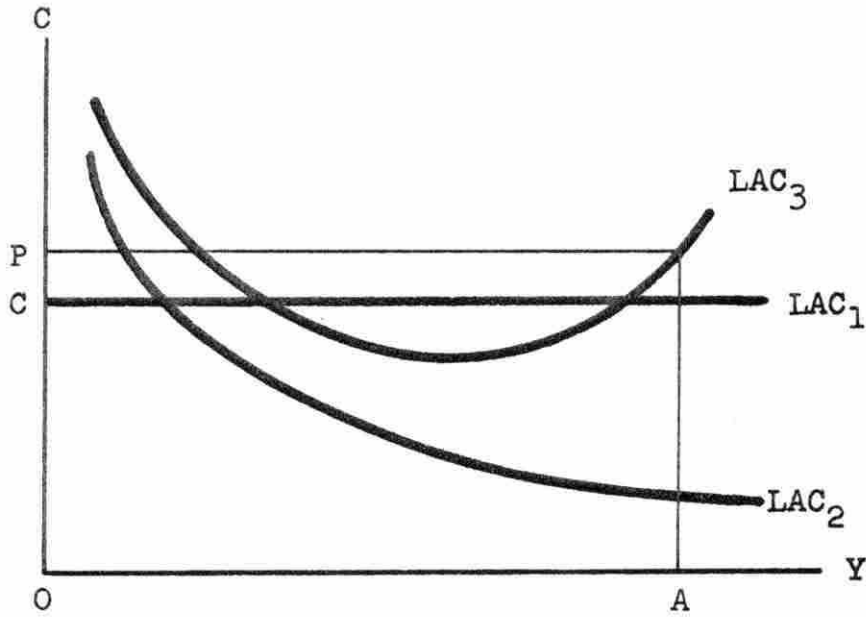


Figure 7.1. Long-run cost curves on farm firms

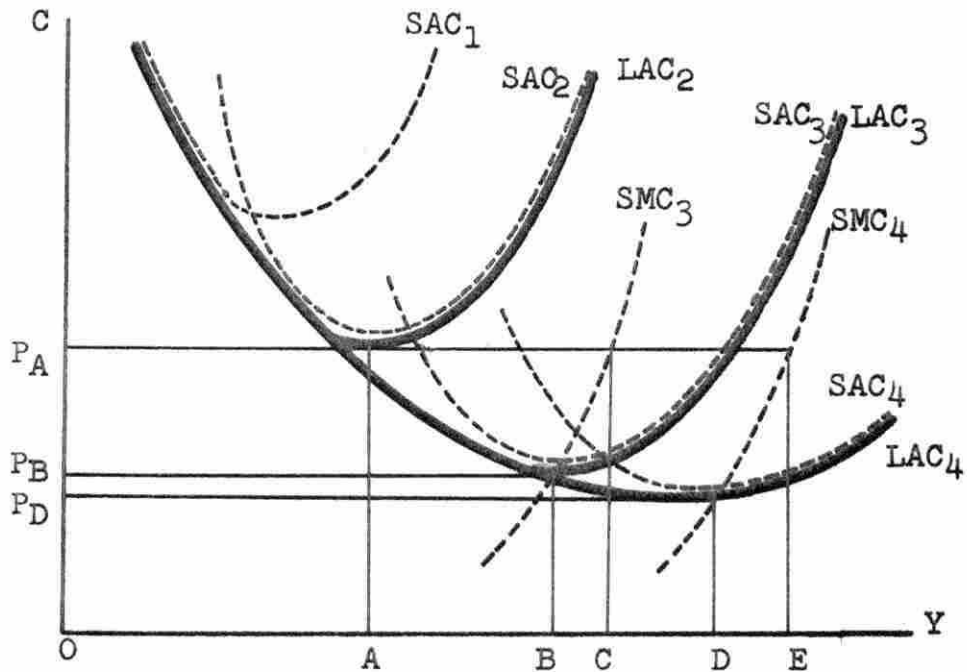


Figure 7.2. Changes in long-run cost curve due to mechanical improvement--increased cost economies associated with farm size

the range of declining cost is not in equilibrium and it has an incentive to expand its size in order to take advantage of size economies.

On the other hand, if the long-run cost curve curls up beyond a certain level of output as LAC, any increase in output beyond a point (A) where the cost is equal to the price of output will reduce income. Therefore, the farm has no incentive to increase its size beyond point A.

2. Mechanical improvements and farm size

How does technological change affect the cost economies associated with the size of farm firms? There are two hypotheses with respect to the effect of mechanical improvements on cost economies.

a. Increasing cost economies of large size First, mechanical improvements have the effect of increasing the cost economies of size. This is clearly stated by Heady.¹

Suppose the existing long-run cost curve is shown by LAC_2 , containing two short-run cost curves SAC_1 and SAC_2 (Figure 7.2). SAC_1 shows the situation in which a farm has a set of machinery whose work capacity corresponds to a certain acreage size. SAC_2 shows a combination of another set of machinery and a larger acreage of land which corresponds to this machine size.

¹See (III, B, 3).

Suppose a larger set of machinery whose cost curve is shown as SAC_3 is introduced in society. It further increases the acreage size a worker can handle and reduces labor cost per output. Since there exist three sets of machine-land combinations in agriculture, the long-run cost will be LAC_3 . If, in the meantime, mechanical improvements add another set of machines which is represented by SAC_4 , the long-run cost curve will shift again to the right (LAC_4).

If the farm has LAC_2 and the price is p , its long-run equilibrium output will be A . As the cost curve shifts to LAC_3 and LAC_4 , the short-run optimum output will go up to C and E , when output price remains constant. The equilibrium output will be B and D , if competition forces the price to go down to the long-run equilibrium level (p_B and p_D).

This situation appears to be actually taking place in U.S. agriculture. As a result of mechanical changes, the cost economies of size are rapidly increasing. In other words, the optimum farm size is rapidly increasing and it (= optimum size) is already considerably greater than the average size farms have reached.

b. Labor saving In the first case discussed above, it was hypothesized that mechanical changes only increase the cost economies of large farms. This is the result of our assumption that the improvements keep adding new sets of machinery which enable a worker to handle an increasing

acreage of land. Under this situation, the farms which get access to the latest machine technology are those which are able to expand their size to a desirable level under the new machine set. The operators of small farms who cannot expand size to this level due to resource limitations have to be satisfied with perhaps a somewhat larger farm but one that is less than the optimum.

There may be some mechanical improvements that contribute to labor saving on farms whose size varies. The introduction of a new engine which is more powerful but not much more expensive than the original one might induce a labor saving effect independently of size. An improved type of field machine may have the same effect.

Cost reduction due to this type of improvement will take place on farms of all sizes rather uniformly, as shown in Figure 7.3 (from LAC_1 to LAC_1' ; from LAC_2 to LAC_2'). It differs from the first type of change in which cost decline takes place only in the higher range of farm size.

As discussed earlier (IV, C, 2), income may increase as a result of indirect effects. Labor released by the improvement will be employed either within the farm or in nonfarm income earning activities. Within the farm, as pointed out in chapter IV, an expansion of farm size and the re-employment of released labor is probably the effective means of increasing income. In this case both large and small farms

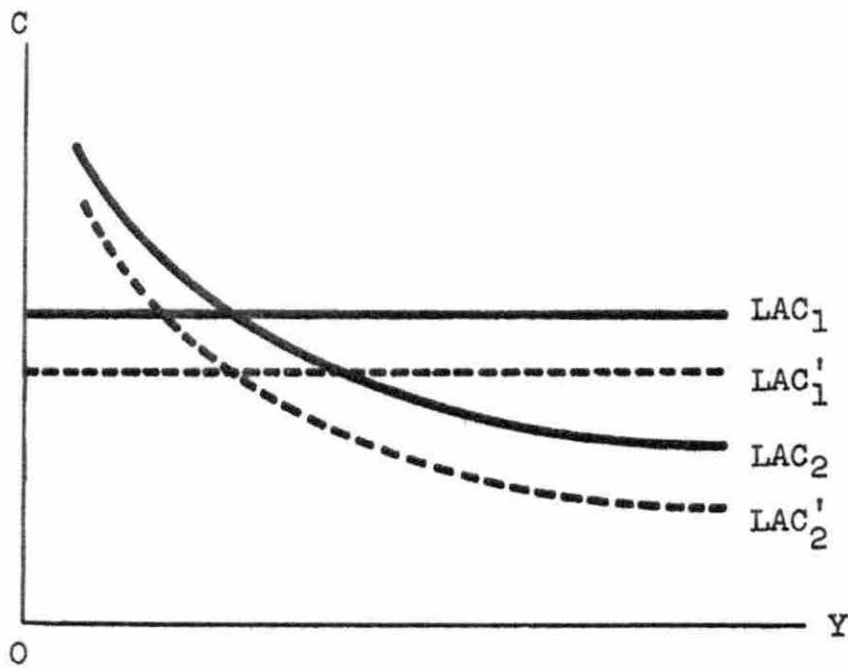


Figure 7.3. Changes in the long-run cost curve due to mechanical improvement--labor saving effect

have an incentive to expand their size of operation.

3. Mechanical improvements and income inequality

In chapter III (III, B, 1), it was hypothesized that (1) there is wide difference in the size of operation among farm firms. In this chapter (VII, A, 2), it was hypothesized that (2) as a result of mechanical improvements, the expansion of farm size is probably the most efficient means of increasing farm income because the optimum size of operation tends to go up very rapidly.

A third hypothesis is examined in the rest of this chapter: (3) The large farm has a greater capacity to expand its size of operation than the small farm.

If this third hypothesis turns out to be true, as well as the first and the second ones, it follows that income inequality between the large and small farms tends to increase as a result of mechanical improvements.

B. Farm Growth

The hypothesis to be examined is as follows: The large farm has greater capacity to expand the size of operation than the small farm.

It has been shown (III, A, 2) that a set of restrictions is imposed on the availability of new inputs because the farm is operating within the framework of the family farm. On the other hand, the process of farm firm growth is nothing but a

series of entrepreneurial activities involving the acquisition of additional inputs. Given market conditions and the state of technological knowledge, it follows that the rate of farm firm growth depends on the farms' capacity for resource acquisition.

1. Farm firm growth

In order to examine our hypothesis, we have to examine the problem of farm firm growth. It is not possible to give a full picture of growth from a theoretical point of view. Our attempt here is simply to extract relevant factors from the existing research data and examine whether these factors have differential effects on the growth process between large and small farms.

In the theory of the firm, the word "growth" is used with two meanings (Penrose, 51, p. 1). First, it means an increase in quantity. Firm growth in this sense is an increase in productive capacity. Second, it means changes in quality and structure, that is, changes in the firm's product mix, in input structure, in managerial organization, and so forth. Firm growth is usually followed by output increase. It also calls for a new set of inputs in moving from one short-run cost curve to another. The firm may be required to have improved management in order to co-ordinate a larger and more complex production unit.

In this chapter, however, the qualitative aspects of

growth are not explicitly analyzed. This is partly justified by the fact that our cost curves already reflect difference in input structure. It is also justifiable because farm firm growth usually involves less structural change than that of industrial firms.

2. Procedure of analysis

Robinson (53) has examined the optimum firm size related to five different criteria. These criteria were:

- (1) Optimum technical unit
- (2) Optimum managerial unit
- (3) Optimum financial unit
- (4) Optimum marketing unit
- (5) Effect of risks and fluctuation on farm size

This is a useful classification. We could apply it directly to farm firm growth. However, the tradition in agricultural economics has been to pay almost exclusive attention to the technological aspect, although risk and uncertainty consideration has been another factor frequently referred to (Heady, 30, pp. 535-561; Johnson, 39, pp. 66-71). This is probably because the farm firm has a less complex managerial, financial and marketing structure, and the major factor determining farm size is its technical attributes. We are following this tradition. We have already examined this technical aspect with respect to farm size and growth. It has been shown that a rapid change in tech-

nology is a major thrust toward larger farm size.

The above discussion has provided us with a static description of size economies. But little has been said of the costs of growth (Robinson, 53, pp. 120-121). The costs of growth are divided into three major categories: (1) The cost of acquiring new physical inputs needed for growth. (2) Additional risk involved in the growth process. (3) Additional managerial efforts needed during (and after) the growth period. These three categories of the costs of growth are examined in the following sections.

C. Availability of Labor and Land

1. Labor

Do most farms need additional labor in order to expand their size of operation? Since the availability of labor from the farm family is limited, labor could be a serious obstacle to growth whenever it involves a considerable increase in labor. However, mechanical improvements have had the effect of substituting capital for labor and have pushed farms in the direction of using less labor per acre of land or per animal. This change has made labor relatively abundant on the farm. Within the range of farm size we are concerned with, therefore, farm growth accompanied by an adequate set of machinery and equipment tends to contribute to the full employment of the existing labor rather than to labor shortage. It does not appear, therefore, that labor

is typically a major limiting factor in farm growth.

2. Land

What about the availability of land? In crop farming, and very often in livestock farming, control over additional land is frequently the most effective means of farm firm growth. Let us leave the financial aspect of land acquisition to the discussion of capital accumulation. We are concerned here with the availability of land either through purchase or leasing.

First, leasing is an important means of expanding farm size. Brewster and Wunderlich state (9, p. 218):

"Leasing is the most common means of separating ownership and control of the resources used in farming and is expected to remain so in the near future. Although the number and proportion of census-defined 'tenants' is declining, the proportion of land under lease remains relatively constant . . .

"For example, more than 42 percent of the farmland in the high income areas of the Corn Belt and the eastern Great Plains is rented. Areas of low farm income, on the other hand, have small percentages of land under lease. The Southeast has less than 25 percent of its farmland under lease; the Northeast, only 14 percent."

Does the large farm acquire needed land in the form of leasing more easily than the small farm? If the contract is on a crop-share basis, it depends partly on relative crop yields (per acre). Crop yield per acre on the large farm may be higher due to better management and better farming practices. If, on the other hand, greater labor

hours per acre contribute to higher yield through more intensive care of the crop, the small farm has an advantage over the large farm. It is hypothesized that better management and higher technological level which tends to be associated with the large farm are more important factors determining yield per acre than greater labor hours which tend to be associated with the small farm. This is because greater man-hours of labor per acre do not necessarily mean more intensive care of crops. It may simply mean that the small farm has a less efficient set of machinery than the large farm. If this is the case, the large farm is in a more favorable competitive situation in leasing additional land than the small farm.

In the case of purchase, the large farm also appears to be in a better situation. A dollar spent in purchasing land will yield greater net return to the large farm than the small farm through better management and higher technological level. Thus the large farm can bid a higher price for land.

Although there are few empirical data which are related to our question, it appears that the large farm is in a somewhat more favorable competitive situation than the small farm in obtaining land needed for farm growth.

D. Capital Accumulation

Farm firm growth is most often referred to as a process of capital accumulation (16). Among many aspects of farm

growth, almost exclusive attention has been paid to the availability of capital and the farm's investment behavior. The supply of investment fund comes from two sources. One is from the family's own saving. The other is from borrowing.

1. Family saving

The amount of investment in farm growth out of saving can be written in the following equation:

$$\begin{aligned} &\text{Farm investment from family saving} \\ &= \text{Family's total income} \\ &\quad - \text{Consumption} \\ &\quad - \text{Investment in nonfarm income earning} \\ &\quad \quad \text{opportunities} \end{aligned}$$

Let us examine the farm family's choice between consumption and saving. First, ignoring nonfarm income, the family's earning is directly related to farm size (II, B, 2). Second, our earlier analysis indicates that, due to the increasing rate of substitution of future income for present consumption as income level becomes higher, the large farm tends to save a greater portion of its total income and invests it in new income opportunities (III, C, 3). Third, the large farm's willingness to bear risks tends to be greater than that of the small farm (III, D, 1). All these considerations appear to suggest that the large farm has a greater capacity (both in the absolute and relative terms)

to invest in farm growth.

Out of total saving, the farm family has to decide on the allocation of investment between farm and nonfarm income earning opportunities. The allocation is determined by the expected rate of return to (and risks involved in) these alternative investment opportunities. Disregarding the family's money holding for precautionary motives, the family will invest its saving in the farm as long as the marginal rate of return to this investment is greater than the expected rate of return to nonfarm investment. If the latter is different between large and small farms, the proportion of the amount not reinvested in the farm to total family saving also may differ. There also may be difference in the family's capacity for portfolio management. But in many cases, it does not appear that such difference would be sufficient to offset the effect of the income difference on the size of the farm investment fund. In general, therefore, the farm's investment fund would be directly related to family income.

2. Borrowed capital

The above discussion suggests that the accumulation of capital through the family's own saving may be rather limited, particularly for the small farm. If a rapid growth of the farm is desired in order to increase income, investment funds may have to be raised from outside the farm family.

The availability of investment funds is conditioned by the borrower's and lender's behavior in risk bearing. Capital rationing occurs when the farm fails to invest up to the point where the interest rate (opportunity cost price) is equal to the expected rate of return on the investment (Johnson, 39, pp. 57-59; 66-70). Capital rationing is divided into two categories according to whether it is a result of the borrower's risk aversion or that of the lender. One is called internal capital rationing and the other, external capital rationing (Heady, 30, pp. 550-557).

In general, certain conditions are attached to farm credits in order to insure that the borrower is capable of repaying the debt within a certain time period. Borrowing capacity, therefore, is restricted by the size of the farm's net worth and present earning power. If the expected future income earning power after the investment could be accurately predicted, there would be little reason to restrict credit by present net worth or earning power. But lack of knowledge and resulting uncertainty over the possible outcome of the proposed investment tend to prevent both the borrower and lender from investing and running the risk of sustaining an irretrievable loss. When the farm's equity ratio drops below a certain level, both parties become reluctant to arrange for a loan.

Swanson (65, pp. 68-72) asked a sample of farmers in

southern Iowa what they thought was the optimum amount of borrowing for production purposes. Two hypothetical groups of farmers in different situations were given. For the first group, which consisted of beginning farmers, recommended equity ratios ranged from 62.8 to 72.1 percent. For the second group, which consisted of farmers of age 40 who owned their farms, livestock, and equipment, they ranged from 72.8 to 80.9 percent, depending on their farm values.

The rather high equality ratios desired by farmers are likely to restrict the rate of growth to a narrow range.¹ Its implication for the borrowing behavior of large and small farms is that the latter can increase size by a smaller absolute magnitude than the former because the small farm's earning power and its net worth are less than those of the large farm.

Discussion in this section has shown that the amount of owned and borrowed capital needed for the purchase of machinery, farmland, etc., associated with farm firm growth is closely tied with (1) the farm's present earning power and (2) its net worth, both of which are closely related to farm size. It follows that the large farm is able to grow faster than the small farm in absolute terms.

¹Relationship between the amount of credit used and farm size is examined in those studies by Heady and others (33) and by Bivens and others (5).

E. Managerial Ability and Growth

The operator's managerial input plays an important role in farm firm growth. The faster the rate of growth, the greater managerial activities required for it. The entrepreneur's major function is to search for greater profit opportunities. Search for the opportunities of farm firm growth, in this sense, is one of his most important tasks. But farm firm growth involves a substantial amount of additional entrepreneurial activities compared with the activities which are not related to growth. The amount of investment required and the expected return to it have to be carefully assessed. In order to do so one has to estimate future prices. The process of capital and land acquisition is a painstaking one. The farm needs a drastic and intricate restructuring of its input-output relationships. These considerations suggest the possibility that lack of managerial capability sets a sharp restriction on growth.

It was hypothesized that the operator of the large farm tends to have a higher level of managerial ability than that of the small farm (III, E, 1). If this is the case, the large farm can achieve a given rate of growth more easily than the small farm.¹

¹It may be partly offset by the possibility that the internal readjustment of input structure in the farm firm is greater for the large farm than for the small farm.

F. Summary

There are two major reasons why farm firm growth is desired as the means of increasing farm income. First, ignoring income earning opportunities outside the farm, accumulation of capital or income earning assets is necessary for higher income. Second, recent development in machine technology has been such that an expansion of farm size has become the most efficient means of increasing income. The second reason is subdivided into two. (1) Mechanical improvements have increased the relative advantage of large farm size. The optimum size has been constantly moving up as a result. (2) Mechanical changes have also contributed to labor saving in farms with a wide range of size. Thus an expansion of farm size is an important means of re-employing this released labor on the farm.

It also has been pointed out that labor is not likely to be a limiting factor to growth because it tends to be replaced by capital inputs through mechanical changes.

In addition, the large farm tends to be in a somewhat more favorable competitive situation than the small farm in obtaining additional farmland through purchase or lease. Because of better management, a higher technological level and more abundant operating capital, the large farm is able to obtain a greater return per acre of added land and, therefore, a superior competitive position.

Availability of capital tends to set a limit to farm growth. Internal and external capital rationing due to uncertainty over the expected return on investment limits the availability of borrowed capital to a small percentage of total net worth. Investment out of family saving is also closely related to farm size. The magnitude of farm firm growth during a given time period, therefore, is an increasing function of farm size.

The operator's managerial ability appears to be an important determinant of growth because of the complexity of decision making associated with growth. Inferior management or a low level of entrepreneurial performance by the operator which tends to be associated with the small farm appears to set a restriction on growth.

The above discussion suggests that farm firm growth in response to improved machine technology tends to be greater for the large farm than the small ones. The increase in income generating assets is, therefore, greater on the large farm than the small farm. Productivity of inputs is also greater on the large farm. Thus, the large farm tends to achieve a greater income increase than the small farm. Therefore, income inequality between these farms tends to increase as a result of differential farm firm growth.

VIII. PRODUCT PRICE CHANGES, FACTOR SUBSTITUTION EFFECT AND THEIR EFFECTS ON INCOME DISTRIBUTION

Our analysis of the effect of technological change on income distribution has been based on the assumption that the prices of inputs and outputs remain constant. This usually holds true for outputs only for a short while during which a limited number of farms adopt the improved technique and it causes only negligible effect on prices. But as an increasing number of farms adopt it, the output price begins to decline. This decline occurs because the improvement tends to increase total output (II, A, 4), and demand for farm products is in general price inelastic.

Our first hypothesis in this chapter is that price change due to technological change tends to increase income inequality further than the level which would exist in the absence of price change. The output increasing effect of technological change, as adoption increases, reduces the output price. It reduces the income of both adopters and nonadopters. But nonadopters suffer a heavier loss than adopters because the former continue to use the old technology, while the latter have moved to more efficient ways of production.

As a result of this output price decline, the productivities of inputs fall. The marginal value productivity of a factor decreases as the output price declines. Technological change also induces factor substitution between capital and

labor (IV, C, 1). Due to improved machine technology, the marginal value productivity of labor decreases relative to that of capital. Thus, rewards for labor decline as this factor bears both the price reduction and factor substitution effect of technological change. On the other hand, these effects tend to offset each other in the case of capital. So labor returns tend to fall relative to capital returns. Since the small farm has a smaller ratio of capital to labor, combined capital-labor returns on the small farm tend to fall relative to those on the large farm. In order to obtain higher return to labor, the small farm has either to increase its size of operation through investment (IV, C, 2) or to move labor out of the farm and find employment in nonfarm income earning opportunities.

Our second hypothesis in this chapter, therefore, can be stated as follows: The burden of labor adjustment in response to price decline due to the output expansion effect and change in relative input productivity due to factor substitution effect of technological change falls more heavily on the small farm than on the large farm.

A. Production Costs, Price Changes, Adoption Behavior and Its Effects on Income Distribution

Our first hypothesis is restated here: The output expansion effect of technological change reduces output prices, and this price reduction and the difference in

adoption behavior tends to increase absolute income inequality between large and small farms more than what would be true in the absence of price change.

1. Farm income

Ignoring all nonfarm sources of income, the farm's income is given in the following equation:

$$\begin{aligned} Z &= TR - TVC_N - TFC_N \\ &= Y \cdot (P - AVC_N - AFC_N) \end{aligned} \tag{3a}$$

Z: Farm income

Y: Output

P: Output price

TVC_N , AVC_N : Total and average variable cost
attributable to input not owned

TFC_N , AFC_N : Total and average fixed cost
attributable to input not owned

It is now assumed that all fixed inputs are owned and all variable inputs are either purchased or borrowed. Then,

$$AVC_N = AVC, \quad AFC_N = 0 \tag{3b}$$

AVC: Average variable cost

From Equations (3a) and (3b)

$$Z = Y \cdot (P - AVC)$$

Under our assumption, fixed costs do not affect farm income because fixed inputs are assumed to be fully owned by the farm. Therefore we have to pay attention only to variable cost.

2. Assumptions on cost functions

Our assumptions on the supply curve, i.e., the short-run marginal cost curves of farms A and B (II, E) are as follows: First, the quantity supplied at any price level is proportional to the farms' input size (acreage size, for example). This is shown in Figure 8.1. In the form of equation:

$$\frac{Y_A}{Y_B} = q \quad (4a)$$

q: Rate of farm A's input size to that of farm B ($q > 1$)

Second, the supply increase due to technological change is proportional to input size at any price level. Hence,

$$\frac{Y_A Y_A^*}{Y_B Y_B^*} = q \quad (4b)$$

From Equations (4a) and (4b)

$$\frac{Y_A^*}{Y_B^*} = q$$

Our assumptions on the short-run average variable cost

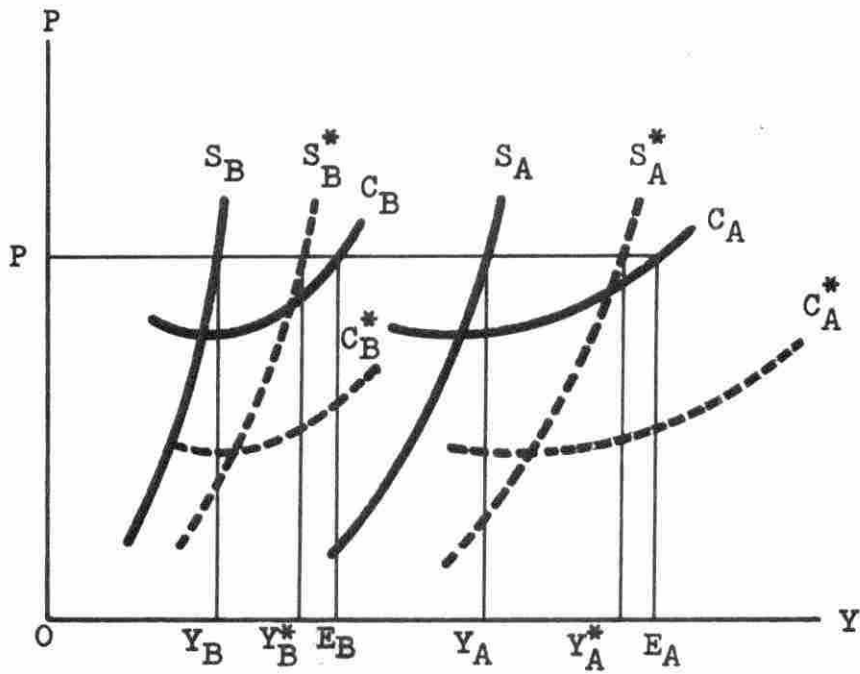


Figure 8.1. Changes in short-run cost curves due to technological change, large and small farms

curves are as follows: (1) The cost curves of farms A and B under the old technology have equal minimum values. So do they under the new technology. But the latter (under the new technology) have lower minimum values than the former. This is also shown in Figure 8.1. (2) Horizontal distance between the cost curve and P-axis in Figure 8.1 is proportional to their farm size, both under the old and new technology. Hence,

$$\frac{E_A}{E_B} = \frac{E_A^*}{E_B^*} = q$$

3. Price decline due to technological change via output increase

Let us assume that the economy consists of two farms, A and B, and that they act as competitors to each other. Figure 8.2 shows the determination of output price before and after the change. It shows the situation in which both A and B have adopted the improved technology. On the other hand, Figure 8.3 shows the situation in which only A has adopted it and B continues to use the old technology. Total supply in the whole economy is equal to the horizontal sum of individual farms' supply curves. In Figure 8.2, S_A , S_B , S_T ; S_A^* , S_B^* , and S_T^* denote the individual and total supply, before and after the change. Given the society's demand DD' , the prices before and after the change are P and P^* ,

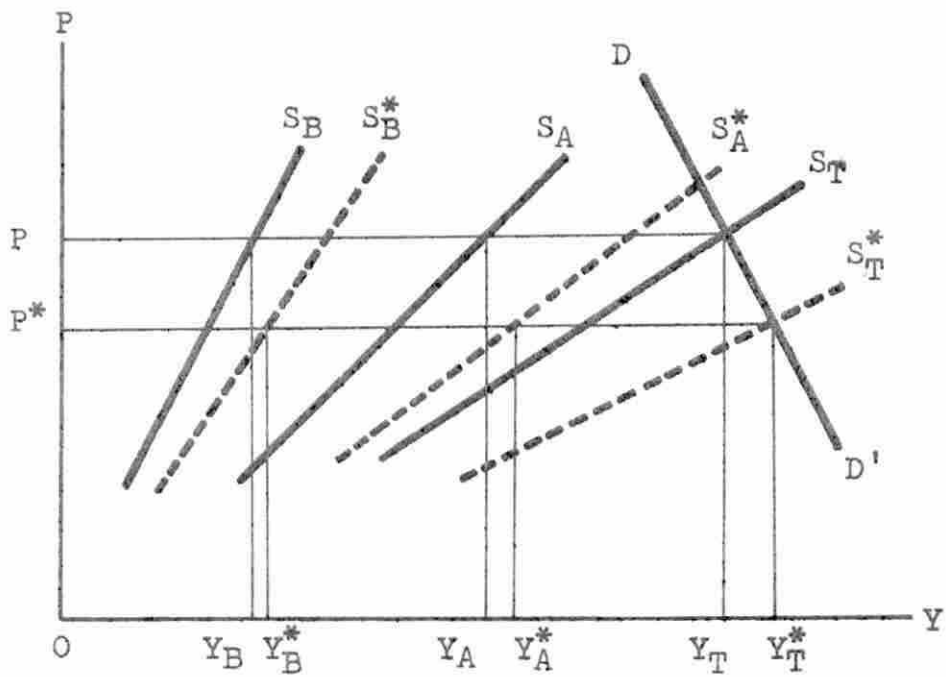


Figure 8.2. Change in output price due to output expansion effect when both have adopted the improvement

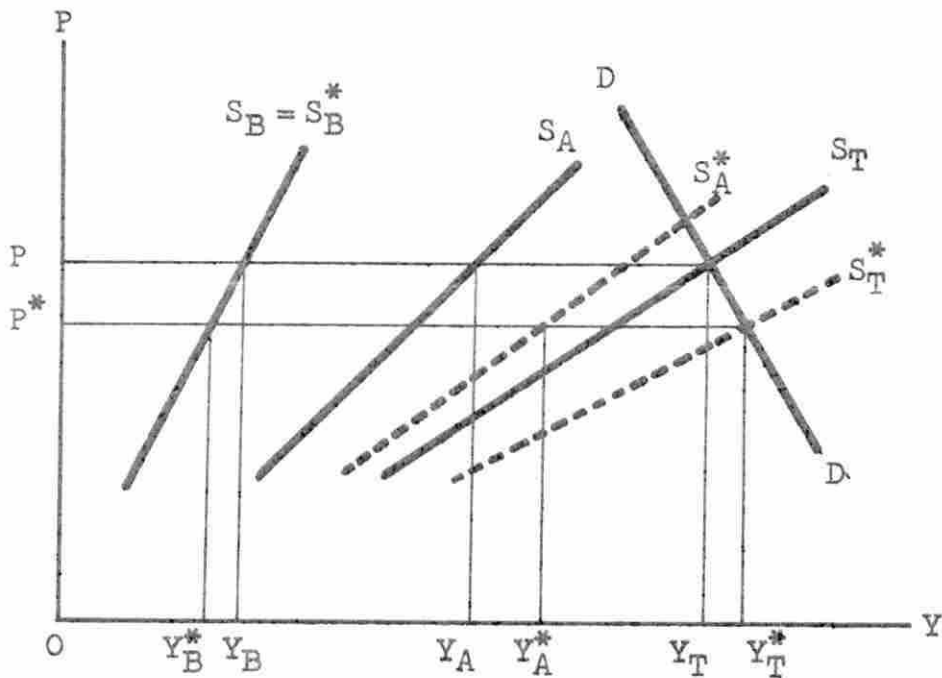


Figure 8.3. Change in output price due to output expansion effect when only large farm has adopted the improvement

respectively.

In Figure 8.3, farm B has not adopted the improved technology and stays on the old supply curve S_A . In this second case, we can point out two major differences from the first case: (1) Price decline due to the change is somewhat less in the second case than the first. (2) The quantity supplied by the nonadopter decreases, while that of the adopter increases, in the second case. In the first case, both increase their outputs.

The size of the price decline depends on three factors: (1) The price elasticity of demand for the product, (2) the shift in supply curves, i.e., the degree to which cost declines due to technological change, and (3) the proportion of adopters in the farm sector.¹ Because the price elasticity of demand for farm product is low, a given increase in output will involve a price decline which is proportionately more than the quantity increase, reducing total revenue.

4. Change in income distribution

We are now ready for the synthesized analysis of the effect of technological change upon the individual farm's income. The cost curves in Figures 8.4 and 8.5 are exactly

¹Although the effect of the increased proportion of the adopters on the price decline cannot be shown in these graphs, it will be easily understood from our foregoing discussion.

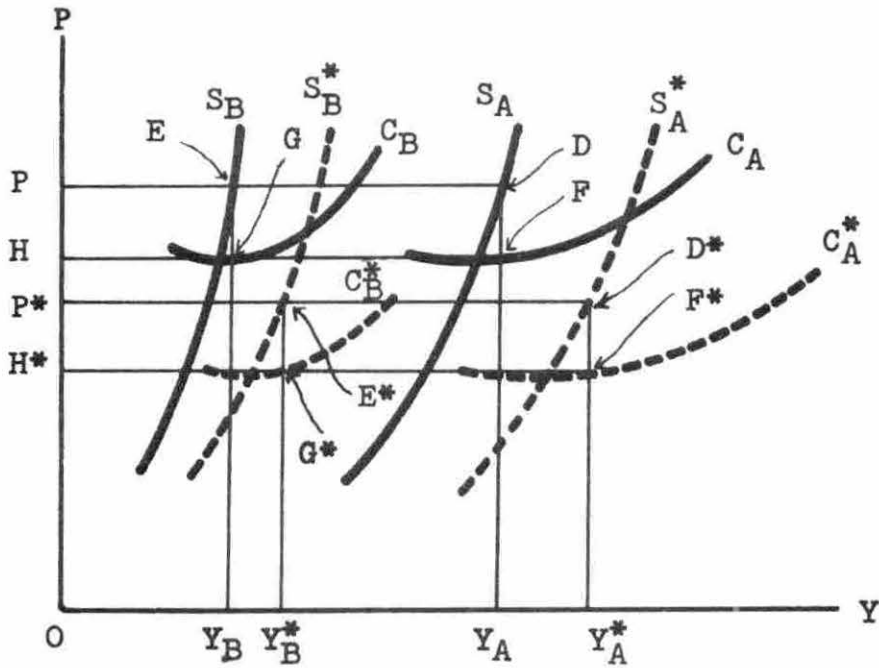


Figure 8.4. Changes in farm income when both farms have adopted the improvement

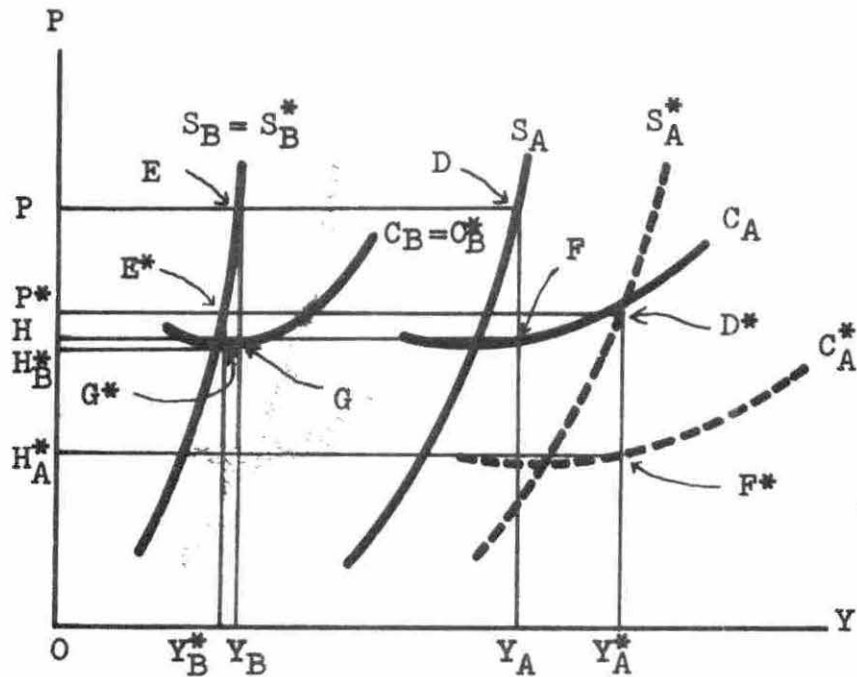


Figure 8.5. Changes in farm income when only large farm has adopted the improvement

the same as those on Figure 8.1. The prices P and P^* are also the same as those in Figures 8.2 and 8.3. Figures 8.4 and 8.5 differ only in that farm B has not adopted the new technology in the second case, while both farms are assumed to have adopted it in the first case.

It would not take a long explanation to show that farm A's income changes from $\square PDFH$ to $\square P^*D^*F^*H^*$, and farm B's income changes from $\square PEGH$ to $\square P^*E^*G^*H^*$. Their total income may increase or decrease depending on the degree to which the price declines. Since both farms are assumed to have adopted the new technology in the first case (Figure 8.4), farm A's price-cost margin is equal to that of B under the new technology as well as the old one. Therefore, their total income is proportional to their output size, i.e.,

$$\frac{Z_A^*}{Z_B^*} = \frac{Y_A^*}{Y_B^*} = q$$

$$\frac{Z_A}{Z_B} = \frac{Y_A}{Y_B} = q$$

where Z_A , Z_B : Z_A^* , and Z_B^* denote the income of farms A and B, before and after the improvement, respectively. Hence,

$$\frac{Z_A^*}{Z_B^*} \bigg/ \frac{Z_A}{Z_B} = 1 \quad (5)$$

Relative income inequality remains unchanged.

Does absolute income increase or decrease? By assumption, both output price and average cost fall. On the other hand, the quantity of output increases on both farms. Total income increases, therefore, if output increases by a greater proportion than the price-cost margin decreases, and vice versa. If this margin increases instead, total income increases.

More data are needed in order to say which is more common case. But at least the possibility exists that total income declines as a result of price decline induced by the output expansion effect of technological change. It occurs when, at the later stages of the diffusion of improvements, the decline in output price is so large that resulting decline in price-cost margin offsets output increase.

What about absolute income inequality between farms A and B? Equation (5) shows that it increases if total income increases on the farm, and decreases if total income decreases.

In the second case where only farm A adopts the new technology and B does not, income difference between the two farms becomes greater than in the first case. In Figure 8.5, farm A's income changes from $\square PDFH$ to $\square P^*D^*F^*H_A^*$, and farm B's income changes from $\square PEGH$ to $\square P^*E^*G^*H_B^*$. Farm B's loss is greater in this case not only because his output is less than it would be if he were in the new technology, but also because his price-cost margin is less than

it would be under the new technology. Hence,

$$\frac{Z_A^*}{Z_B^*} / \frac{Z_A}{Z_B} > 1.$$

Relative income inequality increases in this case.

Absolute income inequality increases at the early stage of diffusion. At this stage, few have adopted the improvement and price decline is not so great as to offset the cost reduction and output increase on farm A. On the other hand, income decreases on farm B because both the quantity and price of output decreases and the cost curve remain unchanged. Thus absolute difference in income between farms A and B widens.

As output price declines further due to increased adoption, the squeeze on price-cost margin falls more heavily on farm B. It is possible that farm B obtains negative income, while farm A still receives positive net income. This situation takes place when the price declines below farm B's minimum cost.

It follows from our foregoing discussion that income inequality between farms A (large size, adopter) and B (small size, nonadopter) increases to a greater extent due to technological change (1) as increase in output due to technological change is greater, (2) as cost reduction is greater, and (3) as price reduction is greater.

B. Changes in Resource Productivity and Their Implications on Resource Adjustment

In this section, the firm's long-run adjustments of input factors in response to technological change is studied. Our hypothesis is as follows: The burden of labor adjustment in response to a decline in the VMPP of labor due to technological change falls more heavily on the small farm than on the large farm.

1. Changes in the VMPP due to technological change

Discussion in section A was essentially a short-run analysis of the effect of an output price decline due to technological change. It was a short-run analysis because the farm firm's input factors were held constant.

However, a decline in output prices due to the output expansion effect of technological change is followed by a decline in the value of marginal physical product (VMPP) of factor inputs. This is shown in Figures 8.6 and 8.7. They show the VMPP of labor and capital inputs.

Suppose, as a result of output expansion effect of technological change, the short-run equilibrium price declines from P to P^* (VIII, A, 3). Let us define a ratio r as follows:

$$r = \frac{P^*}{P} \quad (r < 1)$$

Then the VMPP of labor declines from M_L to M_L^* ; that of

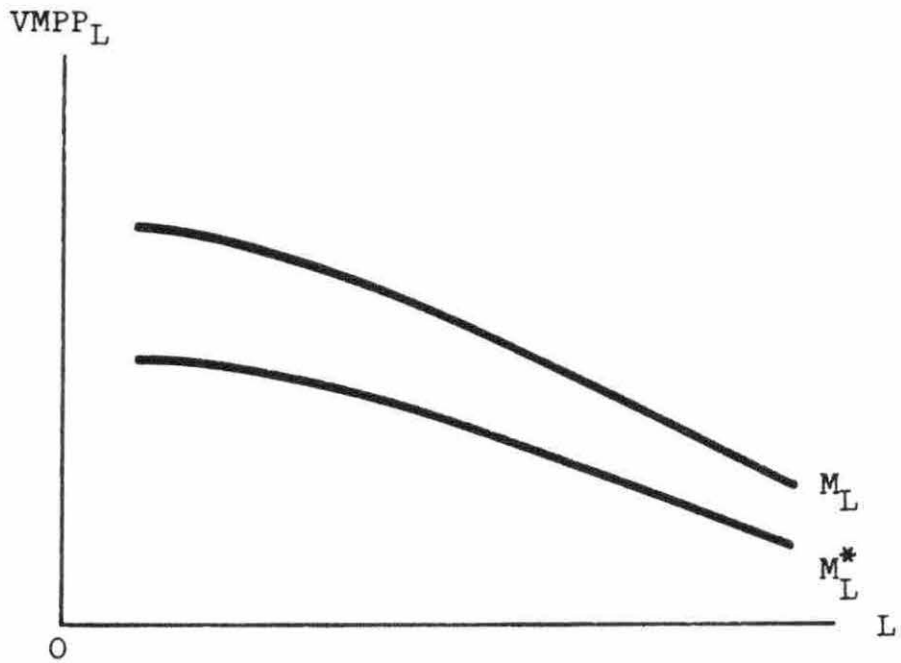


Figure 8.6. Changes in the VMPP of labor due to output expansion effect

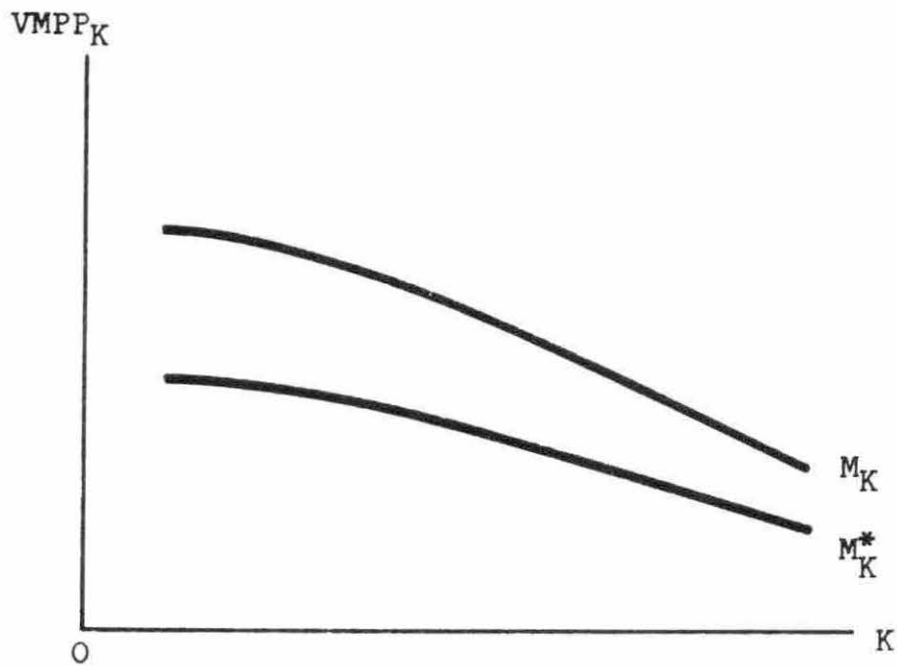


Figure 8.7. Changes in the VMPP of capital due to output expansion effect

capital, from M_K to M_K^* . It is easily understood that both decline by the same proportion, i.e.,

$$M_L^* = r \cdot M_L$$

$$M_K^* = r \cdot M_K$$

It has also been shown that there has been another class of technological changes which have increased the marginal physical product (MPP) of capital relative to that of labor input (IV, C, 1). Mechanical improvements have contributed mainly to this effect. The situation is shown in Figures 8.8 and 8.9. The VMPP of labor declines from M_L to M_L^1 , while that of capital increases from M_K to M_K^1 .

We can view these changes in the VMPP of factors as the accumulated effects of a series of technological changes which the farm has undertaken during a given time period. Some changes contribute mainly to output expansion and the others cause factor substitution.

Total effects of these changes during the period are shown as M_L^{**} and M_K^{**} in Figures 8.8 and 8.9. The total effect on the VMPP differs between labor and capital input. Both the output expansion effect and factor substitution effect reduce the VMPP of labor. Thus, M_L^{**} is substantially lower than the original M_L . On the other hand, the substitution effect increases the VMPP of capital, thus offsetting

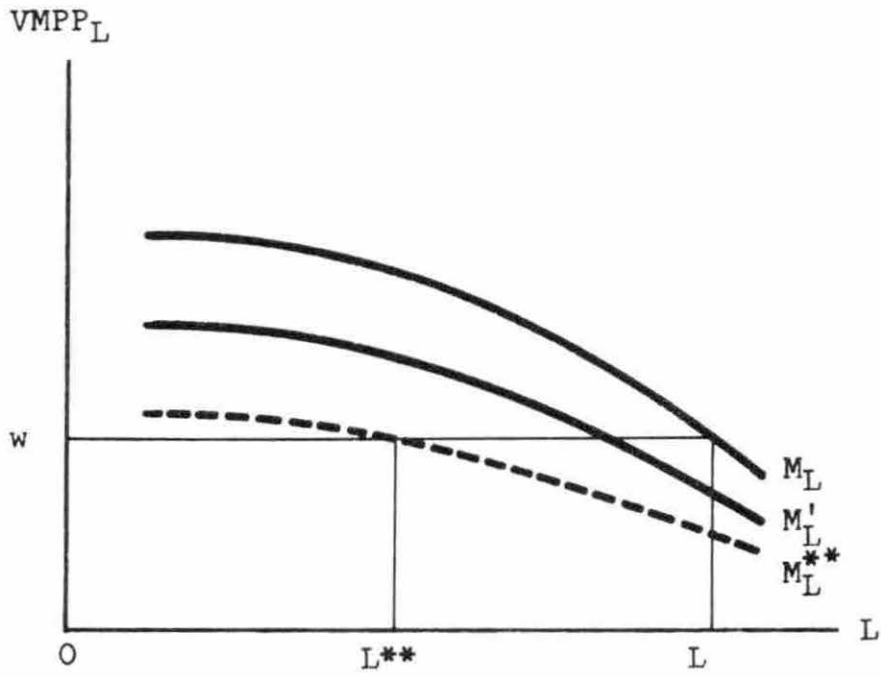


Figure 8.8. Changes in the VMPP of labor due to combined effect

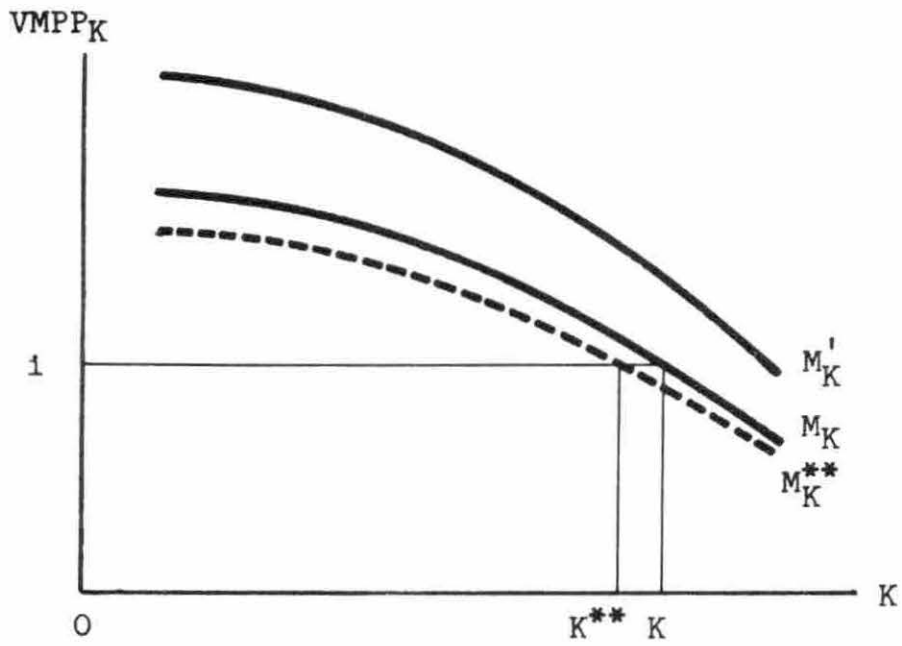


Figure 8.9. Changes in the VMPP of capital due to combined effect

the depressing effect of output expansion. We cannot conclude whether M_K^{**} is greater or less than the original M_K . But the relative difference between M_K^{**} and M_K will be less than that of labor.

Suppose the opportunity costs of labor and capital are w and i , respectively. Suppose the farm had been in equilibrium at L of labor and K of capital. As a result of technological change during the period, the optimum employment level has changed to L^{**} and K^{**} , respectively. To achieve the optimum under the new technology, labor has to be reduced by a large amount, $L^{**}L$, while change in capital is relatively little ($K^{**}K$). Therefore, a relatively large part of burden of adjustment would fall on labor.

2. Labor adjustment in large and small farms

Since it was shown that the major burden of adjustment falls on labor input and that capital input receives less serious impact from technological change, only labor adjustment is analyzed here.

Our assumptions on the farms' input-output relations are as follows: (1) Inputs consists of only two factors, i.e., labor and capital. (2) Both farms A and B have the same production function. (3) The large farm's (A's) capital-labor ratio is greater than that of the small farm (B).

Figure 8.10 shows the VMPP of these farms and its decline

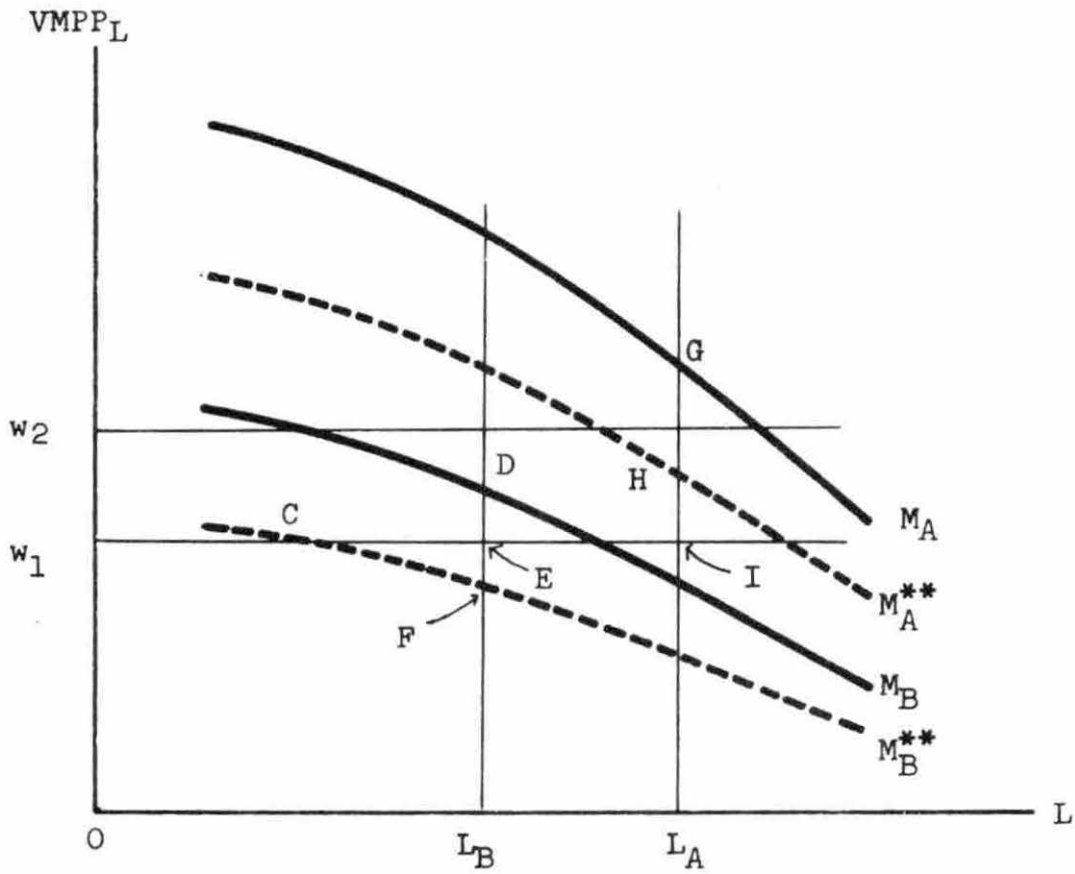


Figure 8.10. Labor adjustment in response to changes in the productivity of labor, large and small farms

due to technological change. Farm A has higher VMPP of labor than farm B because farm A has a greater amount of capital combined with each unit of labor input. The VMPP of labor declines for both farms from M_A to M_A^{**} and from M_B to M_B^{**} due to technological change.

Suppose farms A and B originally used L_A and L_B of labor, and the opportunity cost of labor is equal to OW_1 . Under this condition, labor input on both farms obtains a VMPP greater than its opportunity cost ($L_A G$ and $L_B D$). After the change, however, farm B's VMPP is less than the cost of labor (by EF), while that of farm A is still greater than the labor cost (by HI). In other words, farm B can increase its income by reducing its labor input to $W_1 C$ and employing this released labor in nonfarm income earning activities.

If the labor cost is W_2 , even farm A has to reduce its labor input. Farm B, in this case, has to reduce labor by a greater amount than farm A. In fact, in the situation shown in Figure 8.10, farm B has to withdraw its labor completely.

Another way of increasing labor return is to increase capital input so that the MPP of labor increases. This is exactly the situation examined in relation to farm growth (VII, A). In order to keep the VMPP of labor equal to its opportunity cost OW_1 , farm B has to increase its capital

input up to the point where its VMPP curve passes point E.

Which of these two possible courses of adjustment farm B takes depend on (1) the availability of investment funds to the farm and (2) the difficulty of transferring labor to nonfarm jobs. As analyzed in chapter VII, the small farm tends to have difficulty in obtaining additional resources required for farm firm growth. The major part of adjustment in the small farm, therefore, appears to fall on labor movement out of agriculture.

C. Summary

Technological change tends to strengthen its income-unequalizing forces through output price change. The small farm tends to be late in adopting improved technology compared with the large farm. This causes unfavorable effects on the small farm's income through two paths. First, it foregoes an opportunity to produce at a lower cost (chapter VI). Second, the output price goes down because, as an increasing number of people begin to take advantage of the improved technology, the products supplied to the market increase due to the output expansion of the change. Unless demand for the product increases, its price goes down. The impact of price decline is typically more severe on the small, high cost farm which has not readied itself for this squeeze by adopting the new technology.

Incidentally, the possibility was shown that output

increase due to technological change reduces the income of both large and small farms. It is due to inelastic demand for the product. Even if some farms gain, it is likely that the industry as a whole loses in terms of total farm income.

This output expansion effect of technological change causes a decline in the VMPP of factors through output price reduction. It reduces the values of marginal physical products of both labor and capital. On the other hand, the factor substitution effect of technological change tends to reduce the VMPP of labor relative to that of capital. The net change in factor productivity due to these two effects of technological change is that the VMPP of labor declines substantially and that of capital changes relatively little. Since the small farm has a greater proportion of input in the form of labor than the large farm, combined capital-labor returns on the small farm tends to fall relative to those on the large farm.

Given the cost of labor input at a certain level, the farm's rational behavior is to reduce its labor input to a point at which the VMPP of labor is equal to the opportunity cost of labor. Since the large farm has a greater amount of capital input combined with a unit of labor input than the small farm, the VMPP of labor in the former tends to be greater than in the latter. Although it declines as a result of technological change in both farms, it tends to

drop to a lower level on the small farm than the large farm. In order to equalize the VMPP of labor to its opportunity cost, the small farm has to achieve a greater amount of resource adjustment, either by increasing capital input or moving its labor out of agriculture. Due to the difficulty the small farm tends to encounter in obtaining resources required for farm firm growth, the major part of its burden appears to fall on labor adjustment through out-of-farm movements.

IX. SUMMARY AND CONCLUSION

Technological change in agriculture tends to increase the inequality of income distribution among farm families in the United States.

The mechanism through which inequality increases is as follows:

Technological change is a process in which new more productive inputs are introduced into production. The new inputs induce output expansion and factor substitution effects. Adoption of the new input becomes profitable when the marginal value product exceeds the price of the factor.

The immediate effect of technological change is to increase the early adopter's factor income because the output expansion effect enables him to produce a greater amount of output from resources under his control. The benefit of this improvement, however, accrues only to the adopter. The high income farmer tends to be an earlier adopter of the improvement, while the low income farmer tends to be a later adopter. As a result, income inequality becomes greater compared with the situation in which both adopt it simultaneously.

Under the impact of technological change, both farms and markets are pushed out of equilibrium. One possible reaction to this disequilibrium is a change in product price. As an increasing number of farms adopt the improved

technique, product supply increases. While the early adopters reap the full gain of the improvement because few have adopted it and the price has not fallen, later adopters gain much less or not at all, depending on the amount of price decline. If demand is price inelastic, the larger output will sell for less total revenue. Farmers who have not adopted the improvement are placed in the more unfavorable position cost-wise. Since the large farm tends to be an earlier adopter and the small farm, a later adopter, income inequality between them becomes greater compared with the situation in which the output price does not change.

Another feature of technological change is its disequilibrating effect on the farm firm. Mechanical improvements tend to displace labor employed on the farm. Unless this released labor finds profitable alternative employment, the benefit of the improvement is not fully realized. The expansion of farm size is the most effective means of re-employing this released labor within the farm. Farm firm growth in response to improved machine technology tends to be greater for the large farm than the small farm. It means that the large farm achieves a greater increase in income generating assets and higher resource productivity than the small farm. Thus, income inequality between these farms tends to increase as a result of differential farm firm growth.

Our examination of the effects of technological change has an important implication for farm resource readjustment.

The output expansion effect of technological change causes a decline in the productivity of both labor and capital inputs. On the other hand, the factor substitution effect tends to reduce the productivity of labor relative to that of capital. The net change in factor productivity due to these two effects is that labor productivity declines substantially and that of capital changes relatively little. Since the small farm has a smaller capital-labor ratio than the large farm, total factor returns on the small farm tend to fall relative to those on the large farm. In order to maintain higher return to labor, the small farm has either to increase its size of operation through investment or to move labor out of the farm and find employment in nonfarm income earning opportunities. Because of the greater difficulty experienced in obtaining resources required for farm firm growth, a major part of the burden of labor adjustment falls on small farms in the form of farm to nonfarm transfers.

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